F-35 Joint Strike Fighter (JSF)

Executive Summary

Test Strategy, Planning, and Activity

- The F-35 Joint Strike Fighter (JSF) program focused on completing developmental testing (DT) and verifying compliance with JSF contract specifications by the end of CY17. The program completed two reviews of the DT work remaining and deleted test points in an attempt to stay on schedule. Some test points were considered to be in excess, but others were deemed important for DT or OT. Despite the test point deletions, continued test delays, particularly for mission systems and F-35B flight sciences, will likely push the end of DT into the first or second quarter of CY18, even as time and funding are running out for System Development and Demonstration (SDD).
- Preparations for IOT&E are progressing, although the program will not meet several of the readiness criteria until late CY18; as a result, formal entry into IOT&E will not occur before then.
- The F-35 Joint Program Office (JPO) plans to transition into the next phase of development – Continuous Capability Development and Delivery (C2D2) – beginning in CY18, to address deficiencies identified in Block 3F development and to incrementally provide planned Block 4 capabilities. However, the original C2D2 schedule was not executable due to inadequate test resources in the timelines allocated for both developmental and operational testing to field the planned new capabilities. The program's C2D2 acquisition strategy and development and delivery timelines were under review at the time of this report.

Completing SDD

Developmental Testing

- Flight sciences testing for all variants continued into CY17.
  - F-35A testing completed in March 2017, with the exception of drag chute testing – a Norway-unique test requirement.
  - F-35B testing continued throughout CY17 and will not be complete until early CY18. The need for test-unique tail coatings to prevent overheating the horizontal tails at high airspeed test points, repairing unanticipated cracks in the main landing gear and structural frame, and engine restrictions prohibiting some flight operations resulted in delays to testing.
  - F-35C work included testing of the redesigned outboard wing structure, required to support carriage of the AIM-9X air-to-air missile on a pylon.
- Block 3F mission systems testing continued throughout CY17. DOT&E estimates mission systems testing will continue through February 2018. The program will not be able to completely mitigate the many open deficiencies by the end of SDD, resulting in shortfalls in fielded Block 3F capabilities identified in the JSF Operational Requirements Document (ORD), capabilities the F-35 needs in combat against current threats.



- Static structural and durability testing continued in CY17 for the third lifetime of the F-35A and F-35C test articles (one lifetime is 8,000 equivalent flight hours). F-35A testing completed in October 2017 and F-35C testing at the end of CY18.
- The JPO suspended durability testing for the F-35B after completion of the second lifetime of testing in February 2017; the test article had so many repairs it was no longer representative of the production aircraft. The program has not yet procured another durability test article for the F-35B to begin the third lifetime of testing. The effect of the failures observed and repairs required during the first two lifetimes of testing on the service life certification of the F-35B aircraft is still to be determined. The service life for all three variants is planned to be 8,000 hours, however the F-35B service life may be less than that, even with extensive modifications to strengthen the aircraft already produced.

Mission Data Load Development and Testing

- The U.S. Reprogramming Laboratory (USRL) continues to operate with cumbersome software tools and outdated or incomplete hardware. The lab began creating Block 3F mission data files (MDFs) in the summer of 2017, and it will take 12 to 15 months to deliver a fully-verified mission data load (MDL), made up of a compilation of MDFs, for IOT&E.
- Installation of improved radio frequency signal generators within the USRL test lines, necessary to partially address shortfalls in the replication of realistic signals, was delayed until the JPO placed Lockheed Martin on contract in November 2017.

- The lab test lines need a number of key hardware upgrades to effectively and efficiently develop Block 3F MDFs, and to test and verify their signal detection, identification, and geolocation performance in scenarios representative of combat against the advanced adversaries for which the F-35 was designed.
- The Department programmed $45 Million in FY14-15 for upgrades, but the JPO failed to initiate the contract actions.
- The USRL procured 16 new radio frequency signal generator systems known as Advanced Pulse Generators (APGs) – 8 for each of 2 reprogramming test lines – which will overcome the lab's signal fidelity shortfalls, but still will not provide enough signal density.
- The USRL plans to complete installation and checkout of the APGs, and the new computer hardware that controls them, in the fall of CY18. The installation was delayed until the JPO put Lockheed Martin on contract in November 2017 to conduct the security certification, accreditation, and configuration management processes necessary to obtain authorization to operate in the new configuration. This process is expected to take a year to complete.
- Even after the installation and certification of the new configuration, the lab will still lack a sufficient number of signal generators to simulate a realistic, dense threat laydown with the multiple modern surface-to-air missiles, combat aircraft, and many supporting air defense radars that make up such a laydown.

• Substantial additional investments that have yet to be fully planned or funded are required as soon as possible to upgrade the USRL in order to support F-35 C2D2 MDL development.
  - The C2D2 plan includes new Technical Refresh 3 processors and other new hardware.
  - Concurrent F-35 development and production has resulted in multiple fielded F-35 configurations, many of which will remain active during the C2D2 phase. The USRL, or an additional reprogramming lab, will need to have the capability to simultaneously create and test MDLs for existing and future avionics hardware and software configurations.

Weapons Integration and Demonstration Events

• The JPO completed planned Block 3F Weapons Delivery Accuracy events in CY17 for bombs and missiles, with 15 of 27 results still in analysis. These events have continued to be a source of discovery of deficiencies, and frequently paused progress until corrections could be developed and tested.

• The JSF Operational Test Team (JOTT), along with the associated Service operational test squadrons, conducted weapon demonstration events for both air-to-ground bombs and air-to-air missiles. The JOTT conducted these activities in accordance with a DOT&E-approved test plan using Block 2B and Block 3i operational test aircraft.
  - The air-to-ground weapons events identified mission systems-related deficiencies that adversely affected the completion of the find, fix, track, target, engage, and assess kill chain. These deficiencies included errors in the Launch Acceptability Region (a range displayed to the pilot for the weapon release to meet terminal requirements), the inability of the pilot to confirm coordinates sent to the Joint Direct Attack Munition (JDAM), and deficiencies associated with the Electro-Optical Targeting System.
  - The air-to-air weapons events identified classified integration problems and pilot-identified deficiencies, as well as mission planning and debriefing shortfalls – all of which the JOTT documented in formal deficiency reports.

• The test centers continued gun testing on all variants in CY17. The gun capability is new to the Block 3F weapons suite.
  - Integration, helmet alignment, and line-of-sight problems discovered with the first F-35A air-to-ground aimed firing in February 2017 delayed further testing until the problems could be addressed. Once allowed to proceed, accuracy testing of the F-35A gun showed that it consistently had a long and to-the-right aiming bias, a deficiency that the JPO and Lockheed Martin are investigating.
  - Initial accuracy testing of the F-35B and F-35C podded guns showed better results than that of the F-35A model. Both the F-35B and the F-35C gun pods exhibited the same right aiming bias as the F-35A, however the long bias is not manifested in the podded gun systems.

LFT&E

• In FY17, the live fire test team completed the final F-35 LFT&E ballistic vulnerability test series using the F-35C full-scale structural test article. This test series completed the testing defined under the LFT&E Alternative Test Plan that provides the information needed to adequately assess F-35 vulnerability to the prescribed threats.

• Lockheed Martin completed final ballistic vulnerability analyses for all three F-35 variants against four likely threats. DOT&E is in the process of evaluating the results.

• The JPO evaluated the chemical and biological agent protection and decontamination systems during full-up system-level decontamination testing. The test plan to assess chemical and biological decontamination of pilot protective equipment is not adequate; the JPO does not plan to test either the Gen III or the Gen III Lite Helmet Mounted Display System (HMDS).

• The JPO and DOT&E have not received a report from the Navy on the results of vulnerability testing completed in 2016, which tested F-35B electrical and mission systems against electromagnetic pulses. DOT&E is awaiting the Navy's report in order to adequately assess this vulnerability before the Full-Rate Production decision.

• The 780th Test Squadron at Eglin AFB, Florida, completed ground-based lethality tests of three 25 mm round variants against armored and technical vehicles, aircraft, and personnel-in-the-open targets. The rounds tested were the PGU-32/U Semi-Armor Piercing High Explosive Incendiary round, PGU-47/U Armor Piercing High Explosive Incendiary

with Tracer round, and PGU-48/B Frangible Armor Piercing round. The results are classified.

Operational Suitability

- The operational suitability of the F-35 fleet remains below requirements and is dependent on work-arounds that would not meet Service expectations in combat situations. Over the previous year, most suitability metrics have remained nearly the same, or have moved only within narrow bands which are insufficient to characterize a change in performance.
- Overall fleet-wide monthly availability rates remain around 50 percent, a condition that has existed with no significant improvement since October 2014, despite the increasing number of new aircraft. One notable trend is an increase in the percentage of the fleet that cannot fly while awaiting replacement parts – indicated by the Not Mission Capable due to Supply rate.
- Reliability growth has stagnated. It is unlikely that the program will achieve the JSF ORD threshold requirements at maturity for the majority of reliability metrics. Most notably, the program is not likely to achieve the Mean Flight Hours Between Critical Failures threshold without redesigning aircraft components.

Autonomic Logistics Information System (ALIS)

- The program attempted to test and field ALIS software version 2.0.2.4 throughout CY17. Testing identified deficiencies, some of which the program addressed with corrections prior to fielding. After converting four operating locations to ALIS 2.0.2.4, the Marine Corps units at Marine Corps Air Station (MCAS) Yuma, Arizona, suspended flight operations in June after determining that ALIS was not properly tracking life usage on engine components.
- The program addressed deficiencies with ALIS 2.0.2.4.4, which began testing at Nellis AFB, Nevada, in September. This testing discovered additional deficiencies that caused the Air Force to stop fielding ALIS 2.0.2.4.4 until the program corrected the deficiencies. The Air Force restarted fielding ALIS 2.0.2.4.4 at Eglin AFB, Florida, in November 2017, to be followed by Luke AFB, Arizona, in January 2018.
- The program completed development of ALIS 2.0.2.5 in late CY17 to address some of the existing deficiencies and usability problems within ALIS and upgrade the browser to Internet Explorer 11. This version will include a filtering function designed to decrease false alarms in the Prognostic Health Management System, but no new capabilities.
- ALIS 3.0, the last increment to be released within SDD, has begun regression testing and the JPO expects it to be ready for fielding in CY18. Even though the program has deferred many of the capabilities planned for ALIS 3.0 to ALIS 4.0, the schedule is at risk.

Cybersecurity Testing

- The JOTT continued to conduct cybersecurity testing on F-35 systems, in partnership with certified cybersecurity test organizations and personnel. The testing was conducted in accordance with the DOT&E-approved cybersecurity strategy.
- In 2017, the JOTT conducted Cooperative Vulnerability and Penetration Assessments (CVPAs) and Adversarial Assessments (AAs) of ALIS 2.0.2.4 at all three levels of operation:
  - Autonomic Logistics Operating Unit (ALOU), the collection point and hub for global F-35 logistics data
  - Central Point of Entry (CPE), the component for collecting and staging the data distributed to and from field locations
  - Squadron Kit (SQK), the operational component at the field units
- The AAs did not all complete satisfactorily due to events beyond the control of the JOTT; the JOTT is planning to reschedule uncompleted portions of the AAs in CY18.
- Cybersecurity testing in 2017 showed that some of the vulnerabilities identified during earlier testing periods still had not been remedied.
- More testing is needed to assess the cybersecurity structure of the air vehicle and supporting logistics infrastructure system (i.e., ALOU, CPE, and SQK) and to determine whether, and to what extent, vulnerabilities may have led to compromises of F-35 data. The JOTT has scheduled this testing in CY18.

IOT&E Readiness

- Despite good progress in preparations for starting IOT&E, the program will not complete all readiness criteria until late CY18.
- The 23 aircraft OT fleet will not complete modifications to the Block 3F production-representative configuration until August 2018.
- Required aircraft instrumentation and integration with the test ranges need to be completed and tested prior to starting formal test. These include the Air-to-Air Range Infrastructure system, Air Warfare Battle Shaping system, and flight certification for the Data Acquisition Recording and Telemetry pod. The program should complete testing of all required aircraft instrumentation required for IOT&E test adequacy.
- The Joint Simulation Environment, although not required for start of IOT&E, will likely not be completely accredited before the completion of the open-air portion of IOT&E.
- The program continued working to address unresolved technical deficiencies. These include open deficiency reports identified during developmental testing, modifications to the pilot escape system, a growing number of physiological incidents, production line quality lapses, inadequate tire durability for the F-35B, deficiencies with the helmet display and night vision camera, and restrictions in air refueling for the F-35B and F-35C. The operational effect of these deficiencies, if unresolved, will be assessed during IOT&E.

System

- The F-35 JSF program is a tri-Service, multinational, single-seat, single-engine family of strike aircraft consisting of three variants:
  - F-35A Conventional Take-Off and Landing
  - F-35B Short Take-Off/Vertical-Landing
  - F-35C Aircraft Carrier Variant
- The F-35 is designed to survive in an advanced threat environment (year 2015 and beyond). It is also designed to have improved lethality in this environment compared to legacy multi-role aircraft.
- Using an active electronically scanned array radar and other sensors, the F-35 with Block 3F software is intended to employ precision-guided weapons (e.g., GBU-12 Laser-Guided Bomb, GBU-31/32 JDAM, GBU-39 Small Diameter Bomb, Navy Joint Stand-Off Weapon version C1) and air-to-air missiles (e.g., AIM-120C Advanced Medium-Range Air-to-Air Missile (AMRAAM), AIM-9X infrared-guided, short-range, air-to-air missile).
- The SDD program was designed to provide mission capability in three increments:
  - Block 1 (initial training; two increments were fielded: Block 1A and Block 1B)
  - Block 2 (advanced training in Block 2A and limited combat capability with Block 2B)
  - Block 3 (limited combat capability in Block 3i and full SDD warfighting capability in Block 3F)
- The F-35 is under development by a partnership of countries: the United States, United Kingdom (UK), Italy, the Netherlands, Turkey, Canada, Australia, Denmark, and Norway.

Mission

- The Combatant Commander will employ units equipped with F-35 aircraft in joint operations to attack targets during day or night, in all weather conditions, and in heavily defended areas.
- The F-35 will be used to attack fixed and mobile land targets, surface units at sea, and air threats, including advanced aircraft and cruise missiles.

Major Contractor

Lockheed Martin, Aeronautics Company – Fort Worth, Texas

Test Strategy, Planning, and Activity

- Developmental Testing
  - As of November 6, 2017, the JPO had collected data and verified performance to close out 252 of 476 (53 percent) contract specification paragraphs; 2,516 of 3,452 (73 percent) success criteria derived from the contract specifications had been completed.
  - The JPO completed two reviews of remaining mission systems testing in CY17 and deleted test points in an attempt to keep developmental flight testing on schedule. Some test points were considered to be in excess, but others were deemed important for DT or OT. The deleted test points included those needed for air-to-air gun accuracy, IOT&E instrumentation, and validation of the IOT&E simulation. Despite these cuts, the projected completion of Block 3F mission systems and flight sciences testing has continued to slip into the first or second quarter of CY18. The delays are caused by immature capabilities, continued discoveries, development of corrections, and regression testing, as well as typical test attrition for ground aborts, weather, etc.
  - Staffing at the test centers decreased as qualified, cleared personnel left due to uncertainty over program funding and manning in FY18. The program recently sought to reassure the test centers that funding is available, but decreased staffing continues to adversely affect flight test operations and data analyses.
  - The "final" Block 3FR6.3 software for SDD was released in October 2017, but this planned final version has already been superseded by two additional software updates; more software patches will likely be needed as the program continues to work ongoing problems with weapons and avionics.
  - The F-35A gun has been consistently missing ground targets during strafe testing; the program is still troubleshooting the problems.
  - The F-35B ground test article is unable to start third-life structural testing due to the extensive repairs that were required to complete the second-life testing. The JPO has not yet funded, nor put on contract, a new ground test article.
  - Although the time and funding for SDD are running out in CY17, it is clear that SDD-related work will continue well into CY18. The program's proposed new C2D2 plan attempts to mitigate some of the SDD unresolved deficiencies by funding two more deficiency-fix software releases and flight test in CY18.
- Preparations for IOT&E. The JPO, Lockheed Martin, and the JOTT continued to prepare for IOT&E. Despite significant effort and progress since the FY16 DOT&E Annual Report, DOT&E estimates the program will not meet numerous readiness criteria required for a formal IOT&E start until late CY18.
  - The JPO planned to complete DT by the end of CY17, but flight testing will likely be completed no earlier than the first quarter of CY18 due to delays and problem discoveries (particularly for F-35B flight sciences and mission systems testing).
  - The Services' airworthiness authorities and the JPO plan to incrementally release, by variant, flight clearances

for the Block 3F envelope and weapons releases. All variants are not projected to have the full weapons and envelope clearances until the second quarter of CY18. The airworthiness authorities and weapons contractors have concerns with certifying the full planned Block 3F weapons and flight envelope, so there may be limitations that affect F-35 mission effectiveness in both IOT&E and fielded aircraft.

- The MDL that the operational test squadrons will use for IOT&E will not be complete and verified until the third quarter of CY18. Poor software tools and late delivery of Block 3F software to the USRL have hindered mission data development.
- Modifications to all of the 23 operational test aircraft, most of which are from early production lots and require avionics and structural modifications to the production-representative Lot 9 configuration, will not be complete until August 2018. The Services loaned some of their aircraft, which are already instrumented for IOT&E, to assist DT. As a result, these aircraft will not be available to begin the modification process to become production representative for IOT&E until their DT work is complete in late CY17 or early CY18.
- The program will likely not meet test instrumentation requirements until the third quarter of CY18. These include:
  - Air-to-Air Range Infrastructure system, version 2 (AARI 2) integration and testing, required for mission test trials on the Nevada Test and Training Range.
  - Cleared flight envelope for the Data Acquisition Recording and Telemetry (DART) pod. The envelope for the DART pod must be equivalent to that of the internal weapons for Block 3F, since the aircraft carry it internally on a weapons station. The DART pod must be cleared for weapons bay door cycling during simulated weapon launches during IOT&E to ensure operational realism.
  - Air Warfare Battle Shaping (AWBS), which can host AARI 2 on the Navy's Pacific Sea Test Range and China Lake test range.
  - Integration and testing of range threat emitters with F-35 AARI and AWBS.
- ALIS 3.0, planned for use in IOT&E and the completion of SDD, will likely not be ready for fielding until early to mid-CY18
- The Joint Simulation Environment (JSE), needed to assess F-35 capabilities against modern threat aircraft and dense, modern surface-to-air threat laydowns, will not be verified, validated, and accredited (VV&A) until the first quarter CY19 at the earliest; this would be late-to-need for IOT&E.
- Multiple security challenges must still be coordinated and resolved to allow the different types of aircraft, simulated threat systems and international partners to fly together, and for the resulting data to be processed during IOT&E.
- The program is still carrying a large number of unresolved deficiencies involving the air vehicle itself, Block 3F mission systems, ALIS, and mission planning. There are still approximately 1,000 open deficiencies, with only 88 of 301 Priority 1 and 2 "must fix" deficiencies, as reported by the Services, actually in-work as of November 19, 2017. These unresolved deficiencies will likely have a cumulative effect on F-35 mission capability during IOT&E.
- The program continued to develop, verify, and validate Joint Technical Data (JTD), the formal publications used by pilots and maintenance personnel, throughout CY17. Despite the many drawbacks of concurrency, the fielding of aircraft during development helped the program validate JTD modules in the field, particularly for standard, common maintenance actions. Having all Block 3F JTD written and verified is a readiness criterion for formal entrance into IOT&E.

• Continuous Capability Development and Delivery (C2D2)
  - The JPO continued planning for the transition out of SDD to the next phase of development, formerly referred to as "Follow-on Modernization." This phase of development will now include a period of fielding Block 3F software patches, which will primarily address technical debt and deficiencies identified in flight testing into CY19. This will be followed by incremental development and testing of planned Block 4 capabilities at 6-month intervals.
  - DOT&E assessed the original C2D2 schedule was not executable due to inadequate test resources (e.g., test aircraft, high-fidelity instrumentation, and software and mission data reprogramming laboratory lines) and too much new content in the rapid timelines proposed. The program's C2D2 acquisition strategy and development and delivery timelines were under review at the time of this report. Also, the 6-month software release cycle does not align with other increments of capability needed to support the entire JSF system (i.e., ALIS, mission data, training simulators, aircraft modifications), which have historically taken much longer for the F-35, F-22, and F/A-18. The program should re-plan C2D2 to have a more realistic schedule and content that includes adequate test infrastructure (labs, aircraft, and time) and modifications that align the other fielding requirements.
  - Configuration management may become challenging as the Services will have aircraft fielded in multiple hardware and software configurations that will need software and test resources, including instrumented test aircraft.
  - F-35 modernization is on OT&E oversight, so DOT&E will review the content of each C2D2 increment and, if the increment contains significant new capabilities, will require a tailored formal OT&E. DOT&E routinely conducts "agile" OT for other programs, so each OT&E would be tailored to be as efficient as possible while maintaining test adequacy by leveraging integrated testing with DT and focusing on evaluating the new capabilities and affected mission areas.

Developmental Testing

F-35A Flight Sciences

- Flight Test Activity with AF-1, AF-2, and AF-4 Test Aircraft
  - The program completed F-35A flight sciences testing for SDD in March 2017, with the exception of testing the drag chute on AF-2 (a Norway-unique testing requirement). Analyses of the test data are ongoing.
  - Testing in CY17 consisted of four of eight planned AIM-9X weapons separations tests on AF-1. In March, the program determined that the remaining four separation events were no longer required.
  - Flight test activity continued with AF-1 supporting testing as a chase aircraft and AF-2 conducting drag chute testing. AF-4 entered flyable storage in January, after completing the final phase of chemical and biological testing in December 2016.
  - Through the end of October 2017, the test team completed 58 of 62 test flights and 240 of 301 test points planned for the year. The balance of the remaining F-35A testing is for the Norwegian drag chute.
  - The program plans to conduct flight testing of the DART instrumentation pod, which is needed for IOT&E data collection, on AF-1 from December 2017 to January 2018.
- F-35A Flight Sciences Assessment
  - The Air Force airworthiness authorities are analyzing strain loads, flutter (from flight envelope expansion), weapons separations, and weapons bay acoustic and environmental data to determine the acceptable and safe envelope for flight operations and weapons carriage and employment, with both internal and external weapons stores.
    - The program expects to complete analysis and provide Block 3F military flight releases by late CY17, first for fielded Lot 9 aircraft and 2 months later for OT aircraft, which were produced in earlier lots.
  - The full planned F-35A Block 3F envelope is up to Mach 1.6, and 700 knots, and 9.0 g. Whether airworthiness authorities will clear the F-35A for the full planned envelope, for all planned configurations, without limitations remains to be determined.
    - Aerodynamic loads and environmental conditions within the weapons bay have either caused flight certification authorities to impose limitations to the weapons envelope or have caused weapon vendors to impose life limits on the weapons. Excessive temperatures in the weapons bay at low altitudes while at high speeds may result in speed and time restrictions when carrying internal weapons.

F-35B Flight Sciences

- Flight Test Activity with BF-1, BF-2, BF-3, BF-4, and BF-5 Test Aircraft
  - Through the end of October 2017, the test team flew 244 of 321 flights planned for CY17, and completed 936 of 1,337 test points for the year.
  - F-35B flight sciences focused on:
    - Continued data collection of strain loads, flying qualities and weapons separations for clearing the F-35B Block 3F flight envelope (i.e., Mach 1.6, 630 knots, and 7.0 g)
    - High angle-of-attack flying qualities
    - Podded gun fire testing
    - Air refueling operations
    - Ski jump testing to support UK ship-board operations
    - Rolling vertical landing testing
- F-35B Flight Sciences Assessment
  - The program plans to complete F-35B flight sciences testing by January 2018, enabling a military flight release for the full Block 3F flight envelope in May 2018, but delays are likely. As of the end of October 2017, the program had over 500 test points remaining to complete F-35B flight sciences testing.
  - The following discoveries affected F-35B flight sciences testing:
    - Excessive heating on the horizontal tail surfaces limited the time the aircraft could operate in afterburner at a high Mach number to collect necessary strain load data. To reach high Mach number test points, the program designed and installed flight-test-unique horizontal tail thermal barrier coatings on BF-3.
    - Cracks discovered in the main landing gear doors on BF-2 and in the FS472 bulkhead in the right-hand-side weapons bay required repairs which delayed testing.
    - Cracks discovered in the fuselage frame (FS346) and problems with the seal between the aircraft and the gun pod on BF-1 required repairs, delaying airborne gun fire testing.
    - DT aircraft BF-1, BF-2, BF-3, and BF-4 are equipped with an early, flight test-only engine model. Restrictions prohibiting flight operations slower than 60 knots, including hover and vertical landings, delayed testing.

F-35C Flight Sciences

- Flight Test Activity with CF-1, CF-2, CF-3, and CF-5 Test Aircraft
  - Through the end of October 2017, the test team flew 175 of 202 flights planned for CY17, and completed 720 of 950 test points for the year.
  - F-35C flight sciences focused on:
    - Continued data collection of loads, flying qualities, and weapons separations for clearing the F-35C Block 3F flight envelope (i.e., Mach 1.6, 700 knots, and 7.5 g)
    - Weapons separation testing of the AIM-9X missile (external only for all variants), Joint Standoff Weapon (internal only), and GBU-12 bomb (external carriage added for Block 3F)
    - Buffet and loads testing with a redesigned outboard wing structure due to excessive loads observed during testing with the AIM-9X missile on the outboard external pylons
    - Podded gun fire testing

- Ship suitability testing with modified nose gear hold-back procedures for catapult launches to reduce vertical oscillations during launch.

- F-35C Flight Sciences Assessment
  - The program made progress mitigating excessive, disorienting vertical oscillations during catapult launches by reducing the hold-back release load and adjusting pilot procedures. Shipboard launches in September 2017 using these proposed fixes appeared to reduce the oscillations, but data and pilot surveys were still in review as of the writing of this report.
  - Although the test teams completed testing of the redesigned outboard wing structure, any limitations to carrying weapons on the outboard wing stations will be determined by the Navy's airworthiness authorities when they release the F-35C Block 3F flight envelope, expected in the second quarter of CY18.

Mission Systems

- Mission systems are developed, tested, and fielded in incremental blocks of capability:
  - Block 1 (no longer in use, 26 U.S. aircraft delivered in Block 1 configuration)
    - Block 1 provided initial training capability for Lots 2-3 aircraft, but no combat capability. The Services have since upgraded all of these aircraft to the Block 2B configuration through a series of modifications and retrofits. Additional avionics and structural modifications will be required to configure these aircraft in the Block 3F configuration.
  - Block 2A (62 U.S. aircraft)
    - The program designated Block 2A for advanced training capability and delivered 62 U.S. aircraft in production Lots 4 and 5 in this configuration.
    - No combat capability was available in Block 2A. The Services have upgraded all of the Block 2A aircraft to the Block 2B configuration with modifications and retrofits. Additional avionics and structural modifications will be required to fully configure these aircraft in the Block 3F configuration.
  - Block 2B (no aircraft delivered in this configuration; 88 Block 1 and Block 2A U.S. aircraft upgraded to Block 2B)
    - The program designated Block 2B for initial, limited combat capability with selected internal weapons (AIM-120C, GBU-31/32 JDAM, and GBU-12). This block is not associated with the delivery of any lot of production aircraft, but with an upgrade of mission systems software capability for aircraft configurations through Lot 5.
    - Block 2B is the software that the Marine Corps accepted for the F-35B Initial Operational Capability (IOC) configuration, declaring IOC in July 2015.
    - Corrections to some deficiencies identified during Block 2B and Block 3i mission systems testing were included in the latest production release of Block 2B software – version 2BR5.3 – fielded in May 2016.
    - The Services began converting aircraft from these earlier production lots to the Block 3i configuration by replacing the older Technical Refresh 1 integrated core processor with newer Technical Refresh 2 (TR2) processors in 2016, as well as other hardware upgrades. As of the end of October 2017, 69 of the 88 aircraft (39 F-35A, 26 F-35B, and 4 F-35C) remained in the limited Block 2B (Technical Refresh 1) configuration.
  - Block 3i (108 U.S. aircraft delivered; capable of upgrading to Block 3F)
    - The program designated Block 3i for delivery of aircraft in production Lots 6-8 and a portion of Lot 9, as these aircraft are equipped with upgraded TR2 integrated core processors.
    - Block 3i software began flight testing in May 2014, but experienced many delays and problems due to software immaturity and instability during startup and in flight. As a result, the program paused flight testing of Block 3F software in February 2016 (software version 3FR5) and returned to Block 3i development and flight testing, fielding version 3iP6.21 to operational units in April 2016 with improved stability performance. The Air Force declared IOC with Block 3i-capable aircraft in August 2016.
  - Block 3F (7 U.S. aircraft delivered as of the end of October 2017)
    - The program designated Block 3F as the full SDD warfighting capability for production Lots 9 and later, with plans to upgrade the earlier block aircraft in the future. Block 3F will expand the flight envelope for all variants and includes additional weapons, external carriage of weapons, and the gun.
    - Flight testing with Block 3F software began in March 2015. Block 3F software was too unstable for productive flight testing and hampered progress. After improving the flight stability of the Block 3i software, the program applied the corrections to Block 3F software and continued Block 3F testing.
    - Due to immature Block 3F capabilities and discoveries of deficiencies, the program released multiple versions of Block 3F software, including Quick Reaction Cycle (QRC) versions in attempt to quickly address key deficiencies that were blocking test points.
    - The program delivered the final planned version of Block 3F software – 3FR6 – to flight testing in December 2016. However, flight testing in 2017 revealed the need for several more full and QRC versions of Block 3F software. As of late October 2017, the program was preparing a second version of Block 3FR6.3 (3FR6.32), the 31st version of Block 3F, software as it continues work to resolve key remaining deficiencies.
    - Notably, all of the aircraft from earlier production lots (i.e., Lots 2-5) will need to be modified – to include structural modifications and the installation of TR2 processors – in order to have full Block 3F capabilities.

  - The JPO agreed to allow Lockheed Martin to deliver the initial Lot 9 aircraft with Block 3i software. The first Air Force F-35A delivered with Block 3F software was AF-123, a Lot 9 aircraft delivered to Nellis AFB, Nevada, in September, 2017.
  - The production software version of Block 3F, designated 3FP6.2, was released to test in May 2017. The aircraft accepted with the early version of Block 3FP6.2 software are still not cleared for the full Block 3F envelope and have partially tested MDLs.
- Post-Block 3F Development, now referred to as Continuous Capability Development and Delivery (C2D2)
  - The program's post-SDD development program was previously referred to as Follow-on Modernization (FoM). The FoM plan was not executable due to too much content for the planned schedule and inadequate test resources.
  - The program developed the new C2D2 modernization plan in mid-2017. The C2D2 plan attempts to reduce some of the SDD technical debt by funding several needed deficiency correction software releases with limited flight testing in 2018-2019. This phase will be followed by incremental development and testing of planned Block 4 capabilities at 6-month intervals.

• Flight Test Activity with AF-3, AF-6, AF-7, BF-4, BF-5, BF-17, BF-18, CF-3, CF-5, and CF-8 Flight Test Aircraft and Software Development Progress
  - Through the end of October, the six mission systems developmental flight test aircraft assigned to the Edwards AFB Air Force Test Center in California flew an average rate of 10.2 flights per aircraft, per month, slightly above the planned rate of 10.0, and flew 107 percent of the planned number of flights (583 flown, compared to 543 planned).
  - Mission systems testing focused on:
    - Completing Block 3F mission systems development, testing, and deficiency corrections.
    - Completing weapons separation and integration, and testing for the remaining Block 3F weapons, including the Small Diameter Bomb version I, U.S. Navy Joint Standoff Weapon, version C1 (JSOW-C1), UK Paveway IV bomb and Advanced Short-Range Air-to-Air Missile (ASRAAM).
    - Testing of an organic light-emitting diode (OLED) prototype of the Gen III Helmet Mounted Display System (HMDS), designed to correct excessive "green glow" during night carrier operations.
  - The program jumped ahead in the DT Joint Test Plan and conducted many complex missions at the Nevada Test and Training Range to quickly assess each new version of Block 3F software and sign off as many capabilities as possible without doing all the planned and necessary build-up testing.

• Mission Systems Assessment
  - Delays in starting Block 3F testing in 2015, pausing to redo Block 3i work in 2016, and the immaturity of the Block 3F software delivered to flight test caused the program to continue to fall behind schedule in 2017. The program cut many test points in an attempt to finish mission systems flight test in 2017. However, due to continued discoveries and delays, DOT&E estimates Block 3F development and flight testing will likely not finish prior to February 2018. This estimate is based on the JPO's estimates and its intent to close out SDD, transition to C2D2, get to IOT&E, and start full-rate production.
  - Substantial risks are associated with the program's plan to complete SDD and transition to C2D2.
    - As of late October 2017, there have been 31 versions of Block 3F software as the program works to address key deficiencies. However, the program is using test point data from older versions of software to sign off capability specifications and justify baseline test point deletions, even though the old data may no longer be representative of the latest version of Block 3F software.
    - The program's testing, which skipped some of the planned and necessary build-up testing to sign off capabilities, created a shortfall of necessary test data and proved to be inefficient.
      - » While this method allowed the program to quickly sample key capabilities, the more thorough build-up testing of each capability may not have been conducted.
      - » The limited availability and high cost of range periods, combined with high re-fly rates for test missions completed on the Nevada Test and Training Range, make it difficult for the program to efficiently conduct this testing.
      - » The complex mission scenarios are some of the most difficult test points to execute (i.e., full Block 3F capabilities and flight envelope). This course of action adds risk if the JPO does not properly execute and close out SDD with applicable data, sufficient analytical rigor, and statistical confidence. This would likely result in problem discoveries in IOT&E that may require additional corrections and FOT&E.
    - Finally and most importantly, the program will likely deliver Block 3F to the field with shortfalls in capabilities the F-35 needs in combat against current threats.
  - The program planned to provide full Block 3F capability, as defined in program schedules and the Test and Evaluation Master Plan (TEMP), with the first Lot 10 aircraft delivery in January 2018. As required by the National Defense Authorization Act (NDAA) for FY16, the Secretary of the Air Force certified to Congress in September 2016 that these aircraft will have full combat capability, as determined as of the date of the enactment of the NDAA, with Block 3F hardware, software, and weapons carriage. Although the program made good progress in CY17 and will deliver Lot 10 F-35A aircraft in early CY18 with Block 3F hardware, software, and a flight

clearance for carrying weapons, these aircraft will not yet have the full planned Block 3F capability due to the following shortfalls:

- Envelope limitations may restrict carriage and employment of the planned Block 3F missiles, bombs, and gun well into 2018, if not later.
- A set of five mission data loads (MDLs) is required to be built for the final version of Block 3F; each of these MDLs is optimized for a geographically specific area of responsibility (AOR) around the world, including one MDL designed for operational testing and training in the United States. The MDL for operational testing and training is scheduled to be delivered in July 2018 to support Block 3F IOT&E. However, the full set of MDLs required for real-world operations will not be completely developed, tested, and verified until the end of 2019. One of the remaining four is scheduled for release in December 2018, a second in May 2019, and the final two in November and December 2019, presuming the current schedule holds. This extended timeline is due to ongoing delays with Block 3F and the program's failure to provide the necessary equipment and adequate software tools for the U.S. Reprogramming Laboratory (USRL).
- Even after delivery, the initial set of MDLs will not be fully tested and optimized to deal with the full set of threats present in operational test, let alone in actual combat.
- As of late October 2017, the program had 263 Block 3F unresolved high-priority (Priority 1 and Priority 2) performance deficiencies, the majority of which cannot be addressed and verified prior to the Lot 10 aircraft deliveries, with only 88 of these 301 deficiencies being actively worked.
- The program has many known and acknowledged failures to meet the contract specification requirements. The program intends to seek relief from the SDD contract due to the lack of time and funding remaining.
- The JPO projects that dozens of contract specifications and requirements will be open or unmet going into FY18.
- The program estimates Block 3F mission systems testing will extend into early 2018, confirming estimates by DOT&E and the Office of Cost Assessment and Program Evaluation (CAPE) that delivery of full capability in January 2018 is not possible.
- The developmental and operational test teams continue to discover deficiencies and will discover more before and during IOT&E.
- ALIS version 3.0 is necessary to provide full combat capability. However, the program will likely not field ALIS 3.0 until early 2018 due to delays with ALIS 2.0.2.4. The program deferred to ALIS 4.0 capabilities previously designated for ALIS 3.0. ALIS 4.0 is scheduled for release in late 2018, but this schedule is high risk. Newer versions of ALIS software fielded during IOT&E will be evaluated, if possible.

- Finally, IOT&E, which provides the most credible means to predict combat performance, likely will not be completed until the end of 2019, at which point over 600 aircraft will already have been built.
- DOT&E assesses the proposed C2D2 plan is not executable for several reasons:
  - DT resources are insufficient, lacking enough test aircraft and software integration labs for each F-35 configuration, and adequate time for flight test.
  - The proposed rigid 6-month software cycle timeline does not align with required updates to ALIS, mission data, technical orders, training courseware and simulators, airworthiness envelope releases, and modifications for new hardware and weapons, which typically take longer to field.
  - It is unclear how a software production cycle of 6 months will merge with a fielding cycle that is currently 2-3 years on other aircraft, such as the F/A-18 and F-22.

Static Structural and Durability Testing

- Structural durability testing activity
  - Testing of the F-35A and F-35C ground test articles (AJ-1 and CJ-1, respectively) continued into their third lifetime – one lifetime is 8,000 equivalent flight hours (EFH). The JPO suspended testing of the F-35B ground test article (BH-1) after completing only the second lifetime of testing in February 2017.
  - The F-35A durability test article began the third lifetime of testing on March 11, 2016, and completed in October 2017. The test article is currently in teardown and analysis.
  - The F-35B durability test article completed the second lifetime of testing on February 1, 2017. Due to the significant amount of modifications and repairs to bulkheads and other structures, the program declared the F-35B ground test article was no longer representative of the production aircraft, so the JPO deemed it inadequate for further testing. On February 17, 2017, the program canceled the testing of the third lifetime with BH-1 and made plans to procure another ground test article, but has not yet done so.
  - The F-35C durability test article completed the second lifetime of testing (16,000 EFH) on October 29, 2016. The testing for the third lifetime began on April 4, 2017, and reached 17,606 EFH as of August 8, 2017. The JPO projects that lifetime testing on CJ-1 will be completed by December 2018.
- Structural durability testing assessment
  - For all variants, this testing led to discoveries requiring repairs and modifications to production designs and retrofits to fielded aircraft.

  - To date, the JPO has not funded or put on contract a new ground test article. The program should complete contract actions for another F-35B ground test article as soon as possible to begin additional durability testing.
  - The effect of the discoveries and failures during testing on the service life certification of the F-35B is yet to be determined. It may be less than the planned 8,000 hours designed for all variants, even with extensive modifications to strengthen the aircraft.

Mission Data Load Development and Testing

- F-35 effectiveness in combat relies on MDLs, which are compilations of the mission data files (MDFs) needed for operation of the sensors and other mission systems. The MDLs work in conjunction with the avionics software and hardware to drive sensor search parameters so that the F-35 can identify and correlate sensor detections, such as threat and friendly radar signals.
  - The contractor team produces an initial set of MDFs for each software version to support DT during SDD.
  - The USRL creates, tests, and verifies operational MDLs – one for operational test and training, plus one for each potential major geographic area of operation. Operational test aircraft and fielded aircraft use the USRL-generated MDLs.
- The testing of the USRL MDLs is an operational test activity, as arranged by the JPO after the program restructure that occurred in 2010, and consists of laboratory as well as flight testing on OT aircraft.
- Because MDLs are essential software components of F-35 mission capability, the Department must have a reprogramming lab that is capable of rapidly creating, testing, and optimizing MDLs, as well as verifying their functionality under stressing conditions representative of real-world scenarios. This is necessary to support the proper functioning of F-35 mission systems and the aircraft's operational effectiveness in IOT&E, training, and combat. The reprogramming lab must also be able to rapidly modify existing MDLs when intelligence data changes, but this capability has not yet been achieved.
- Although the USRL has the capability to create functioning MDLs for Block 3F and earlier blocks, it does not have a sufficient number of radio frequency (RF) signal generators, which are used to stimulate the F-35 Electronic Warfare (EW) system and the EW functions of the radar, nor are the signal generators able to test and optimize the MDLs under conditions stressing enough to ensure adequate performance against current and future threats.
  - The current reprogramming hardware and software tools are cumbersome, requiring several months for the USRL to create, test, optimize, and verify a new MDL; a time period that delays getting MDLs to operational units. The USRL began creating Block 3F MDFs in the summer of 2017; it will take approximately 12-15 months to deliver the first verified MDL for IOT&E and for fielded Block 3F aircraft. The USRL will then release verified MDLs for the remaining areas of responsibility at approximately 3-month intervals.
- The JPO and Lockheed Martin have yet to complete necessary funding and contracting actions to fully address shortfalls in signal generation capability within the USRL.
  - The Department clearly identified the need for improved USRL capabilities in 2012 and programmed $45 Million in the FY14-15 budgets to address the need.
  - The JPO sponsored a gap analysis study of USRL capabilities, completed in 2014, to determine the lab upgrade requirements at the engineering level before beginning contracting actions. The study concluded that the USRL would need between 16 and 20 upgraded RF signal generator channels for each of the USRL's two test lines, in order to adequately create and test MDFs for the fielded threats examined in the study, using realistic scenarios and threat densities.
  - After considering upgrade proposals from Lockheed Martin, the USRL recently elected to procure eight new RF signal generator systems known as Advanced Pulse Generators (APGs) for each of two USRL test lines, directly from the APG vendor. The USRL recently contracted with the vendor for their installation and checkout, expected to be competed in fall 2018, which will be late to need to support IOT&E. This is the only USRL upgrade that is funded. The installation was delayed until the JPO placed Lockheed Martin on contract in November 2017 to conduct the security certification, accreditation, and configuration management processes necessary to obtain authority to operate in the new, upgraded configuration. Even when this interim upgrade is complete, the USRL will still not have enough signal generators to simulate a realistic threat laydown with multiple modern surface-to-air missile threats and the supporting air defense system radars that make up the signal background in the laydown.
- The program began delivering production aircraft in the Block 3F configuration in September 2017. These aircraft are being delivered with a previous version of Block 3F software and an early, partially tested, and unverified MDL, resulting in an undetermined level of risk if used in combat prior to operational testing.
- To provide the necessary and adequate Block 3F mission data development capabilities for the USRL, the JPO must immediately fund and expedite the contracting actions for the necessary hardware and software modifications, including an adequate number of additional RF signal generator channels and the other required hardware and software tools. Although these actions are already late to need for Block 3F fielding and IOT&E, the capabilities are still urgently needed to support operational Block 3F aircraft.
- Significant additional investments are also required now to upgrade the USRL to support F-35 C2D2 MDL development.
  - The C2D2 plan includes new Technical Refresh 3 processors and other new hardware. Concurrency in development and production during SDD has resulted in

multiple fielded F-35 configurations that will continue to need to be supported long after the development program enters the C2D2 phase. During C2D2 the program will require the USRL, or an additional reprogramming lab, to have the capability to simultaneously create and test MDLs for different avionics hardware and software configurations, including not only whatever ones emerge from the various stages in C2D2 but also all prior active configurations. These different configurations include Technical Refresh 1 (Block 2B), Technical Refresh 2 for Block 3F, new electronic warfare equipment planned for C2D2, an improved display processor, and a new Technical Refresh 3 open avionics architecture for later increments in C2D2.
  - Although the C2D2 hardware upgrades for the USRL should already be on contract, the reprogramming requirements for C2D2 have yet to be fully defined. According to a study conducted by Lockheed Martin, three of the Block 4 capabilities will affect at least one of the models used in the reprogramming laboratory. The JPO must expeditiously undertake the development of those requirements and plan for adequate time and resources in order to ensure the USRL is able to meet C2D2 and MDL requirements.
- As part of IOT&E, the USRL will complete an "Urgent Reprogramming Exercise (URE)." This will evaluate the ability of the USRL, with its hardware and software tools, to respond to an urgent request from a Service to modify the mission data in response to a new threat or new mode of an existing threat.
  - During a URE at the USRL in 2016, the total hours recorded were double the Air Force standard for rapidly reprogramming a mature system. The JOTT identified several key process problems, including the lack of necessary hardware, analysis tools that were not built for operational use, and missing capabilities, such as the ability to quickly determine ambiguities in the mission data.
  - The JPO must correct these problems in order to bring the ability of the USRL to react to new threats up to the identified standards routinely achieved on legacy aircraft. However, the problems will not be addressed by the time IOT&E is projected to start in late CY18.
- In addition to resolving the deficiencies described above, involving overall laboratory capabilities, and the deficiencies in the tools used to develop MDLs, the program must also properly sustain the USRL to ensure a high state of readiness, particularly if the Services have an urgent reprogramming requirement, which could happen at any time for the fielded aircraft. To meet these tasks, the USRL must have all necessary equipment in a functioning status, similar to aircraft availability, which will require a sufficient number of Field Service Engineers (FSE) to assist in maintenance and operation of the lab equipment, and adequate training for laboratory personnel. Also, the USRL requires adequate technical data for lab equipment and enough spare parts and/or supply priority to quickly repair key components.

Weapons Integration and Demonstration Events

Block 3F Weapons Delivery Accuracy and Weapons Integration and Certification

- Activity
  - The table below depicts DT Weapons Delivery Accuracy (WDA) events for Block 3F weapons integration, including those accomplished during this reporting period. The JSF weapons team plans to complete the remaining gun events by the end of CY17.
  - Each WDA event has an overall assessment rating for meeting the weapons integration success criteria to verify compliance with the JSF contract specification.
    - Prerequisite engineering and characterization missions continued to discover deficiencies with mission systems software and hardware for all weapon types.
    - These discoveries of deficiencies in the fire control thread and fusion functionality, as well as the corresponding correction to deficiencies and fix verification, were the pacing items for accomplishment of the weapons events.
  - As shown in the event table, multiple versions of Block 3F software have been required to complete the events, with many created specifically to address deficiencies preventing the next event from proceeding.
  - Most of the AMRAAM events were completed using work-arounds to mitigate limitations induced by outstanding deficiencies that compromised the combat capability of the weapons employment. The JPO, contractor, Services, and JOTT are assessing these weapons integration deficiencies so that problems can be addressed prior to entry into IOT&E and subsequent fielding.
  - Detailed descriptions of technical and weapons employment problems, along with corresponding fixes required to ensure combat performance, are classified.
  - The JPO is also pursuing a structured, combined developmental and operational test strategy for the GBU-49 variant of Raytheon's PaveWay series of bombs.
    - The JPO agreed to integrate the GBU-49 weapon into Block 3F as requested and funded by the Air Force. This additional weapon integration on the F-35A is intended to provide the combat air forces with a more robust moving ground target kill capability.
    - The JPO will include this weapon as an update to the SDD requirement for GBU-12 integration and performance.
    - At the time of this report, the test center had performed one initial captive carry flight to verify safe integration and assess the controls and displays to the pilot. The JOTT, in conjunction with the 53rd Wing at Nellis AFB, is planning six additional GBU-49 weapons delivery events to confirm functionality and weapons integration. The JOTT will augment this by flying a number of IOT&E profiles and weapons events to sufficiently demonstrate and evaluate the operational capability in the IOT&E weapons delivery events.

BLOCK 3F WEAPONS DELIVERY ACCURACY (WDA) EVENTS				
WDA Event	**Weapon(s)**	**Mission Systems Software**	**Date Accomplished**	**Summary Assessment**
105	AMRAAM	3FR6.21	Jul 17	Successful
301	AMRAAM	3FR5.03	Jul 16	Successful
302	AMRAAM+AIM-9X	3FR5.03	Jul 16	Successful
303	AMRAAM	3FR5.03	Aug 16	Partially Successful
306	2 X AMRAAM	3FR6.21	Aug 17	Successful
307	2 X AMRAAM	3FR5.03	Aug 16	Partially Successful
308	AMRAAM + SDB	3FR5.06	Nov 16	Successful
309	2 X AMRAAM	3FR6.21	Jul 17	Successful
311	2 X AMRAAM	3FR5.03	Jul 16	Unsuccessful
314	UK ASRAAM	3FR6.12	Jun 17	Analysis in Progress
315	UK ASRAAM	3FR6.01	Feb 17	Analysis in Progress
316	AIM-9X	3FR5.03	Jul 16	Successful
317	AIM-9X	3FR5.03	Aug 16	Successful
318	AIM-9X BLOCK 2	3FR5.06	Dec 16	Successful
319	GBU-12	3FR6.11	Mar 17	Successful
320	GBU-31	3FR5.03	Jul 16	Successful
321	GBU-31	3FR5.03	Jul 16	Successful
322	2 X GBU-31	3FR5.03	Aug 16	Successful
323	4 X GBU-39	3FR5.05	Oct 16	Successful
324	2 X GBU-39	3FR5.03	Aug 16	Successful
325	SDB	3FR5.03	Jul 16	Successful
327	JSOW	3FR6.22	Oct 17	Successful
328	UK PW-4	3FR5.05	Oct 16	Successful
329	2 X UK PW-4	3FR6.01	Mar 17	Successful
330	A/A GUNNERY	3FR6.22	In Progress	*See note below
331	A/S GUNNERY	3FR6.22	Oct 17	*See note below
332	A/S GUNNERY	3FR6.22	Oct 17	*See note below
333	A/S GUNNERY	3FR6.22	In Progress	*See note below
334	NIGHT GUNFIRE	3FR6.3	In Progress	*See note below

* Flight testing of the different gun systems on the F-35 (internal gun for F-35A and external gun pods for the F-35B and F-35C) revealed problems with effectiveness, accuracy, pilot controls, and gunsights displayed in the Helmet Mounted Display System (HMDS). The synopsis and assessment of specific HMDS problems are classified. The gun profiles include the testing and qualification of four separate 25 mm rounds in the two gun types. The F-35A internal gun testing includes the PGU-23 training round, PGU-47 Armor Piercing High Explosive Incendiary round, and the PGU-48 Frangible Armor Piercing round. The F-35B and the F-35C variants external gun pod testing is limited to the PGU-32 Semi-Armor Piercing High Explosive Incendiary round used by the Marine Corps.

- Assessment
  - The JOTT is assessing three events as candidates to be repeated with additional follow-on OT shots.
    - Events WDA-303 and WDA-307 were partially successful due to control room work-arounds that compromised the operationally representative profiles necessary to support later-planned IOT&E weapons delivery events.
    - Event WDA-311 was unsuccessful due to the combination of weapon performance and the inability of the F-35 to effectively employ the weapon in the planned scenario.
  - The WDA events also provide much of the evidence needed for operational weapons flight clearance certifications.
    - The initial plan for weapons integration and operational stores certifications involved conducting the WDAs on the early Block 3F software versions. The data analyses and certification processes are extensive and lead to a recommendation from the weapon vendors and Lockheed Martin to the Service's flight clearance authorities. Successful tests and analyses would have endorsed the specific weapon and suspension and release equipment for the operational stores certifications that

are required for the military flight release for fielding and IOT&E.
    - Due to limited or problematic test data, the weapon vendors and Service flight clearance authorities have determined that the expected flight clearances for full carriage and employment of the F-35 Block 3F weapons suite may have significant limitations.
    - The JPO is reviewing the problems that may require limitations in the flight clearance. The JOTT will evaluate the effects of potential restrictions to the weapon carriage and release envelopes, including limitations on flight hours and stores combinations. As the technical details and effects of these problems unfold, DOT&E will monitor and assess how any limitations may affect the adequacy of planned IOT&E profiles and the performance of the F-35 in IOT&E and in combat.

Gun Testing

- Gun Activity
  - All three F-35 variants add gun capability with Block 3F. The F-35A gun is internal; the F-35B and F-35C each use an external gun pod. Differences in the outer mold-line fairing mounting make the gun pods unique to a specific variant (i.e., an F-35B gun pod cannot be mounted on an F-35C aircraft).
  - AF-31, the only Block 3F mission systems-capable F-35A test aircraft configured for gun testing, completed the first air-to-ground gun firing at Naval Air Weapons Station (NAWS) China Lake, California, in February 2017.
    - Helmet Mounted Display System (HMDS) alignment problems identified during the test event prevented further weapons demonstration activities with the gun until corrections were developed and tested. The test team accomplished a risk reduction test flight in March while awaiting resolution of the HMDS alignment and line-of-sight problems.
    - AF-31 completed an air-to-ground live fire accuracy event on September 27, 2017, and a gun lethality mission on October 5. Additional testing was ongoing at the time of this report.
  - BF-1 completed the first F-35B airborne gun firing on February 21, 2017. BF-1 then attempted more gun testing in March, but gun pod problems, weather, and range availability prevented the completion of the initial set of scheduled events.
    - BF-1 resumed testing in April, but gun pod seal problems and cracks at the FS 346.5 frame further delayed testing. BF-1 completed airborne gun firing in May to complete the flight sciences testing of the gun pod on the F-35B.
    - BF-17, the only Block 3F mission systems-capable test aircraft configured for gun accuracy testing, completed a gun lethality mission on September 12, 2017.
  - CF-3 performed the first F-35C airborne gun firing on June 6, 2017, and continued more gun testing throughout the month. It completed flight sciences testing with the gun pod in July.
- Gun Assessment
  - F-35A gun accuracy testing on AF-31 demonstrated uncharacterized bias toward long and right of the target. Also, the gunsight display in the HMDS was cluttered and slow to stabilize.
  - The initial F-35B strafing results with the gun pod have been better than those for the F-35A. The aim-point projection through the HMDS was more stable and the F-35B does not appear to have significant angular bias errors like the F-35A. The program will complete accuracy assessments; however, because the program used just a single aircraft per variant to assess compliance with specification requirements, the JPO will make more assessments with OT aircraft before and during IOT&E.
  - F-35C accuracy results with the gun pod to date have been consistent with those observed with the F-35B.
  - The JOTT and the Services will need to develop shot-kill criteria, possibly for each variant, to assess the effectiveness of simulated gun employment during training and test mission trials in IOT&E. Ongoing delays in completing the remaining gun testing and correcting gun-related deficiencies within SDD, especially for the F-35A, are adding risk to the IOT&E schedule.

Air-to-Ground Weapons Demonstration Events

- Air-to-Ground Weapons Activity
  - In 2016, the JOTT and the associated Service OT squadrons conducted 18 GBU-31 and GBU-32 Joint Direct Attack Munition (JDAM) weapon demonstration events (WDEs) and 28 GBU-12 laser guided bomb (LGB) WDEs on range complexes at NAWS China Lake and MCAS Yuma. The number of events accomplished exceeded the number of planned events. A summary of the events appears in the following table.
  - The JOTT planned all of the WDEs as part of operationally representative scenarios constructed to characterize the radial miss distance of air-to-ground weapons employed by the F-35 and to identify any problems in completing the find, fix, track, target, engage, and assess kill chain.
    - Aircraft were loaded with either Block 2BS5.2 or 2BS5.3 (the final Block 2B software).
    - Scenarios included a representative mix of target cueing via voice communications, Variable Message Format (VMF) digital messages, and shoot-list sharing via Multifunction Advanced Data Link (MADL).
    - LGB target designation was performed via self-lasing, airborne buddy-lasing, or lasing by the ground tactical control party. JDAM targeting was accomplished with coordinates generated either by the Electro-Optical Targeting System (EOTS) laser or a synthetic aperture radar (SAR) map.
  - Twenty-two of 28 LGB events and 15 of 18 JDAM events were valid for scoring miss distance. Invalid events include those in which the weapon failed, the scenario was

Weapon Type		Events Planned	Events Conducted					Events Valid for Scoring
			Total	Inert/Live		Variant		
				Inert	Live	F-35A	F-35B	
LGB	GBU-12	16	28	25	3	21	7	22
JDAM	GBU-31	8	15	7	8	15	0	13
	GBU-32	4	3	3	0	0	3	2

not operationally representative (i.e., range restrictions precluded accurate execution of a scenario), or mission systems problems disrupted the kill chain (i.e., a failure to generate target coordinates for JDAM employment or the laser designation wandered off the target during LGB employment). The invalid events for accuracy scoring still provided opportunities to identify kill chain problems.

- Air-to-Ground Weapons Assessment
  - The radial miss distance of these air-to-ground weapons when delivered by the F-35 is consistent with that of legacy platforms. Specific details are classified.
  - Mission systems problems affected the delivery of air-to-ground weapons. A preliminary assessment of these problems appeared in the FY16 Annual Report. Additional details appear below.
  - The Dynamic Launch Zone (DLZ), the aircraft-generated indication of the JDAM launch acceptability region (LAR) in the cockpit, was not consistent with the shoot cue, an indication generated by the actual JDAM in-weapon LAR.
    - The DLZ is based on an outdated LAR model.
    - The DLZ consistently reported being in-range (i.e., that the bomb could reach the target) or in-zone (i.e., that the bomb could reach the target and achieve pilot selected impact conditions) at a greater range than the shoot cue. It also disagreed with the shoot cue at weapon release in 7 of 17 WDEs.
  - The F-35 Block 2B cockpit displays did not allow the pilot to confirm the coordinates passed to the JDAM. The inability to confirm coordinates reduced pilot and ground controller confidence in weapon steering and contributed to the employment of two weapons on the wrong targets during the demonstration events.
    - Rules of engagement in operational areas sometimes require that pilots confirm the coordinates to the ground controller before receiving clearance to drop weapons.
    - For Block 3F, the pilot is now able to see what coordinates are sent to the bomb, but is still not able to see what coordinates are actually loaded in the bomb. The Services are assessing if this correction meets the requirements directed by the rules of engagement in specific areas of operation.
  - The EOTS presented several problems during the air-to-ground WDEs.
    - The EOTS slews rapidly and erratically when passing through the gimbal limit directly out the bottom of the aircraft. During this time, there is a period of seeker de-rotation along the aircraft flight path in which the EOTS cannot be controlled, leading to loss of target track during critical portions of the kill chain, including weapons employment, dive recovery, and battle damage assessment. Even though the pilots were trained to avoid the limit, the problem occurred during several of the WDEs and resulted in two failed attacks.
    - The responsiveness of the Cursor Slew Switch (CSS), which moves the cursor on the Panoramic Cockpit Display, precluded pilots from manually designating moving targets per Air Force tactics, techniques, and procedures.
    - EOTS point tracks were generally stable, but pilots observed cases in which the point track had difficulty differentiating between the target, background clutter, and the target shadow, causing track to occasionally transfer from moving targets to infrared-significant clutter.
    - The EOTS does not provide any lead-point-compute or lead-laser guidance to engage moving targets. The CSS slews the cursor at only one rate, regardless of the degree of displacement of the switch, and does not support manual moving target designation. To engage moving targets, pilots were forced to use simple rules of thumb which may not be effective or allowable in combat, depending on the rules of engagement and the target's speed.
  - Failures of the Fuselage Remote Interface Unit (FRIU), which provides the interface between the aircraft avionics and weapons stations, frequently disrupted missions.
    - If an FRIU failure occurs during an attack, pilots must reset the FRIU to clear the fault and regain communications with the weapon, and then re-attack the target. Several FRIU failures occurred during the WDEs and required minutes-long resets of the Integrated Core Processor.
    - The program has addressed these FRIU failures and recent weapons events demonstrated improved FRIU reliability.
  - Pilots frequently chose to manually enter mission planning data in the cockpit, versus using the Offboard Mission Support workstation, due to the excessive time required to transfer the data from the Portable Memory Device to the aircraft.
    - Manual entry is prone to error and led to inappropriate or incorrect radar mode presets, weapon overlays, steerpoints, sequences, pre-planned target coordinates, communication presets, Link 16 and MADL

assignments, and weapon and fuze settings during WDEs.
    - Although the program has improved load times with updated transfer devices, Portable Memory Device loading still takes too long and is often problematic.
  - The lack of a video datalink or the capability to automatically compute a time-on-target (TOT) degrades the close air support (CAS) mission.
    - The lack of a video datalink required pilots to correlate targets with ground controllers via voice communications, extending the time required for targeting during CAS missions. The poor fidelity of EOTS video further extended the targeting time.
    - The lack of automatic TOT computation increased pilot workload, compared to legacy aircraft. Because pilots had to manually calculate TOTs during the CAS engagements, ground controllers either requested attacks with a time window for weapon impact or an immediate attack with no specified TOT in the majority of events. Of the five events in which a precise TOT was coordinated, two occurred more than 30 seconds from the acknowledged TOT; these attacks would have been aborted doctrinally.
    - The inability to calculate a TOT limits the ability of the F-35 to participate in complex combined arms environment. The program developed a fix to allow the pilot to compute a TOT, but as of the writing of this report, it has not been tested.

Air-to-Air Weapons Demonstration Events

- Air-to-Air Weapons Activity
  - The JOTT, with the Air Force 53rd Wing and the Marine Corps VMX-1 OT flying units, used the range complex over the Gulf of Mexico at Eglin AFB, Florida, to evaluate the ability of Block 2B and Block 3i aircraft to employ the AIM-120 Advanced Medium Range Air-to-Air (AMRAAM) missile in operationally representative scenarios.
    - These scenarios were designed to evaluate the ability of the F-35A and F-35B to accurately find and identify the target, track and engage a simulated hostile aircraft, and support the missile to a kill.
    - The Air Force supported the effort with six F-35A aircraft configured with IOC Block 3iR6.01 mission systems software. The Marine Corps supported the effort with three F-35B aircraft configured with IOC Block 2BS5.3 mission systems software. Both of these mission systems software versions reflected the Service's initial fielding configuration and capabilities.
  - The effort consisted of two CY16 deployment periods: the Air Force deployed in May 2016 and the Marine Corps deployed in August 2016.
    - The two units employed a total of six AIM-120 missiles at the Gulf Test and Training Range Complex against full-scale and sub-scale drone targets simulating combat configurations and flight profiles. These missile shots supported the JOTT test requirements as approved by DOT&E and the combat unit tactics development to support IOC fielding for both Services.
    - The deploying units used the initial deployment quick-look information to update and refine tactics development.
    - Technical problems with validation of the telemetry data stream delayed until 2017 the delivery of missile data required for detailed analysis. Once the technical data problems were resolved, the JOTT performed the required detailed analysis to evaluate the missile shots.
  - The six missile shots supported five OT events. The Marine Corps unit fired one of those missile shots against a specific target profile required by the Marine Corps for initial F-35 tactics development. All six shots were accomplished per the DOT&E-approved test plan and the combat scenarios used the most current tactics as outlined in the applicable tactics manuals. This initial set of OT events yielded tactics observations and identification of key technical deficiencies in the ability of the F-35 to employ the AIM-120 weapons.
- Air-to-Air Weapons Assessment
  - The assessment revealed several problems with the employment of air-to-air missiles in the Block 2B and Block 3i configurations. The test team discovered several classified missile integration problems as well as pilot-identified deficiencies with the controls and displays that affected the combat capability of the F-35 to support the kill chain. The teams also identified problems with the off-board mission planning and debriefing system that hindered effective planning and timely debriefing.
  - The test teams documented these problems in deficiency reports and submitted them via the monthly deficiency review board at the Edwards Integrated Test Force.

LFT&E

F-35 Ballistic Testing and Vulnerability Analyses

- In mid-FY17, the F-35 LFT&E program completed its final ballistic vulnerability test series at the Weapons Survivability Laboratory, NAWS China Lake, California, using the F-35C full-scale structural test article.
  - These tests demonstrated the structural tolerance of the F-35C against realistic ballistic threats, but also showed the probability of threat-induced fires was greater than previously anticipated. Consequently, the JPO revised the fire predictions used in its final analysis of F-35 ballistic threat vulnerability.
  - This test series completed the testing defined under the DOT&E-approved LFT&E Alternative Test Plan that provides the information needed to assess F-35 vulnerability to the prescribed threats.
- Lockheed Martin completed final ballistic vulnerability analyses for all three F-35 variants against four likely threats. DOT&E is in the process of evaluating the results to assess F-35 vulnerabilities.

- The Lockheed Martin assessment compares F-35 vulnerabilities against two sets of requirements: the JSF contract specifications and the JSF ORD.
  - All three F-35 variants met JSF contract specifications in the Prevent Pilot Escape (i.e., damage or injury that prevents ejection) category for three of the four threats. No variant met the Prevent Pilot Escape requirements against one of the threats.
  - For their ability to sustain damage and return to the Forward Line of Troops (FLOT), the F-35A and the F-35C met requirements against two of the four threats (one type of missile warhead fragment and Man-Portable Air Defense System (MANPADS) missiles). No variant met the Return-to-FLOT requirements against two of the threats. The F-35B did not meet the Return-to-FLOT requirements against three of the threats.
  - In comparing against the F-16C in similar configurations, all variants of the F-35 were better than the F-16 in the Prevent Pilot Escape and Return-to-FLOT categories for three of the four threats. None of the F-35 variants could meet the requirements against the fourth threat in either category, nor could the F-16.

Vulnerability to Unconventional Threats

- The full-up, system-level chemical-biological decontamination test on BF-40, a low-rate initial production (LRIP) F-35B aircraft, demonstrated the efficacy of the Hot Air Decontamination equipment and processes. Additional developmental work is required to field an operational decontamination capability. A 2QFY16 event demonstrated that a modified system process and a better insulated shelter could maintain adequate temperature and humidity control inside the shelter, even in a cold-weather environment.
- The program test plan to assess chemical and biological decontamination of pilot protective equipment remains inadequate.
  - Compatibility testing of protective ensembles and masks showed that the materials survive exposure to chemical agents and decontamination materials and processes, but the program has neither tested nor provided plans for testing the fielded Gen III and Gen III Lite versions of HMDS.
  - Gen II HMDS compatibility analysis compared HMDS materials with those in an extensive DOD aerospace materials database. The program plans similar analysis for the Gen III HMDS design. Even if the program understands the material compatibilities, it does not plan to demonstrate a process that could adequately decontaminate either HMDS from chemical and biological agents.
- The Navy evaluated an F-35B against the electromagnetic pulse threat level defined in Military Standard 2169B, but the data and report have not yet been provided to DOT&E. Follow-on tests on other variants of the aircraft, including a test series to evaluate any Block 3F hardware or software changes, are ongoing.

Gun Ammunition Lethality and Vulnerability

- The 780th Test Squadron at Eglin AFB, Florida, completed ground-based lethality tests of three 25 mm gun round variants against armored and technical vehicles, aircraft, and personnel-in-the-open targets. The rounds tested were:
  - PGU-32/U Semi-Armor Piercing High Explosive Incendiary
  - PGU-47/U Armor Piercing High Explosive Incendiary with Tracer (APEX)
  - PGU-48/B Frangible Armor Piercing
- Ground-based lethality tests for the APEX round correlated well with pre-test predictions for round penetrations, but the 780th Test Squadron discovered potential problems with fuze functioning when impacting rolled homogeneous armor at high obliquity.
  - Nammo, the Norwegian manufacturer, conducted additional testing to identify the cause of the dudded rounds during the ground tests and subsequently modified the fuze design to increase reliability.
  - DOT&E will include the effect of the ground-based lethality test data in the ammunition lethality assessment. No additional testing will be conducted.
- The weapons integration characterization of the gun and sight systems for the air-to-ground gun strafe lethality tests commenced in September 2017 and is ongoing at the Naval Air Warfare Center Weapons Division (NAWCWD) at NAWS China Lake. Strafe targets include small boats, light armored vehicles, technical vehicles (pickup trucks), and plywood manikins for each round type tested (similar to targets used in ground-based lethality tests).

Operational Suitability

Activity

- The program continued to deliver aircraft to the U.S. Services and international partners throughout CY17 in production Lot 9. As of the end of September, 235 operational aircraft had been delivered to the U.S. Services and international partners, and assigned to units. These aircraft are in addition to the 14 aircraft dedicated to developmental testing.
- As of the end of September, the U.S. fleet of F-35s accumulated 80,815.5 flight hours
- The following assessment of operational suitability is based on sets of data collected from the operational and test units and provided by the JPO. The assessment of aircraft availability is based on data provided through the end September 2017. Reliability and maintainability assessments in this report are based on data covering the 12-month period ending May 31, 2017. Data for reliability and maintainability include the records of all maintenance activity and undergo an adjudication process by the government and contractor teams, a process which creates a lag in publishing those data. The variety of data sources and processes are the reasons the data have different dates and appear to be delayed.

Assessment

The operational suitability of the F-35 fleet remains at a level below Service expectations and is dependent on work-arounds that would not be acceptable in combat situations. Over the previous year, most suitability metrics have remained nearly the same or moved only within narrow bands, which are insufficient to characterize a trend of performance.

Overall fleet-wide monthly availability rates remain around 50 percent, a condition that has existed with no significant improvement since October 2014, despite the increasing number of new aircraft. One notable trend, however, is an increase in the percentage of the fleet that cannot fly while awaiting replacement parts – indicated by the Not Mission Capable due to Supply (NMC-S) rate – for the entire fleet. The increase in the NMC-S rate is due to inadequate supply support. Concurrency of production and development, lower-than-expected reliability for parts, inadequate fault isolation, and early program decisions to not adequately fund procurement of spares have contributed to the increased NMC-S rate.

Reliability growth has stagnated, as reported in the FY16 DOT&E Annual Report. It is highly unlikely that the program will achieve the ORD threshold requirements at maturity for the majority of reliability metrics. Most notably, the program will likely not meet the Mean Flight Hours Between Critical Failures threshold without redesigning aircraft components, improving Prognostic Health Management (PHM) accuracy, or some combination of both.

- F-35 Fleet Availability. Aircraft availability is determined by measuring the percent of time individual aircraft are in an "available" status, aggregated monthly over a reporting period. The program-set availability goal is modest at 60 percent, and the fleet-wide availability discussion below uses data from the 12-month period ending September 2017.
  - Availability is determined by measuring the combined non-availability rate across three status categories: Not Mission Capable for Maintenance (NMC-M), Depot (in the depot for modifications or repairs beyond the capability of unit-level squadrons), and NMC-S.
    - The average monthly NMC-M rate was 15 percent, compared to the goal of not more than 15 percent. The monthly NMC-M rate exhibited little trend up or down, indicating stable performance. The F-35B variant was down for maintenance more than the F-35A or F-35C, averaging an 18 percent NMC-M rate compared to a 13 percent rate for the F-35A and a 14 percent rate for the F-35C.
    - The average monthly Depot rate was 14 percent, compared to the goal of not more than 13 percent. The monthly Depot rate varied from as high as 24 percent to a low of 11 percent. The depots, along with depot-level repair teams sent to operating sites, repaired or modified the most aircraft in October 2016, largely driven by one-time repairs to faulty insulation of fuel lines on a select number of F-35A aircraft. After that period the depot rate stabilized in the low teens, ranging from 15 percent to 11 percent.
    - The average monthly NMC-S rate was 21 percent, compared to the goal of not more than 12 percent. The NMC-S rate was the primary driver of non-availability, ranging from 16 to 25 percent.
      - The NMC-S rate displayed a slight worsening trend over this period, never falling below 20 percent from February to September 2017, and reaching the highest value in the period of 25 percent in September 2017.
      - Several factors contribute to the high NMC-S rate.
        - Concurrency of production and development has caused the program to build a spares pool based on engineering assessments of reliability, vice actual failure data.
        - The program initially purchased spares to a 20 percent NMC-S rate estimate, which has proven to be optimistic.
        - The program has been late to stand up organic depot capabilities to repair existing parts that have failed but can be refurbished instead of being replaced with new parts, a capability that would reduce the strain on suppliers to produce more spare parts.
        - An immature PHM system (see PHM section later this report for more detail) detects failures which cause removal of parts which actually have not failed. However, these parts are sent back to the original equipment manufacturer and then returned to the supply chain as being "Re-Test OK" (RTOK). These actions add additional backlog to an already overloaded repair system.
  - The average monthly fleet availability rate was 50 percent. The availability rate ranged from 44 percent to 55 percent. Individual operating sites, particularly those with later lot aircraft, surpassed the 60 percent goal in select months over this period. At no point did the overall fleet, nor did the average of any specific variant persistently exceed 60 percent availability; although the F-35C variant surpassed 60 percent availability in three months, with a high of 70 percent in one of these 3 months.
    - This availability rate range was the same as reported in the FY16 DOT&E Annual Report, indicating a stable rate of availability with no trend of improvement.
    - Fleet availability has changed little over the past 3 years. The availability rate first reached 50 percent in October 2014 and has since achieved a maximum 56 percent on two separate occasions.
  - Variant-specific average monthly availability rates were relatively consistent for this period as well, at 51 percent for the F-35A, 46 percent for the F-35B, and 54 percent for the F-35C.
    - In previous reporting periods, F-35B availability was significantly lower than that of the F-35A and F-35C, largely due to a disproportionately high number of

F-35B aircraft going through depot modifications in order to support the Marine Corps declaration of IOC.
  - Starting late fall 2017, a disproportionately large number of F-35C aircraft are scheduled to receive depot modifications. As a result, that variant's monthly availability will likely fall significantly, relative to the other variants, through at least the winter to spring of 2018.
- The table below summarizes F-35 aircraft availability by operating site. The number of aircraft assigned at the end of the reporting period is an indicator of potential variance in availability.

F-35 AVAILABILITY FOR 12-MONTH PERIOD ENDING SEPTEMBER 2017 [1]				
Operating Site	Average	Max	Min	Aircraft Assigned [2]
Whole Fleet	50%	55%	44%	235
Eglin F-35A	38%	49%	30%	25
Eglin F-35C	57%	69%	46%	12
Yuma F-35B	60%	70%	45%	10
Edwards F-35A	51%	70%	13%	8
Edwards F-35B	35%	58%	18%	7
Edwards F-35C	41%	73%	28%	7
Nellis F-35A	53%	67%	46%	16
Luke F-35A	50%	55%	44%	60
Beaufort F-35B	38%	52%	27%	28
Hill F-35A	70%	81%	22%	27
Amendola F-35A [3]	60%	80%	29%	4
Iwakuni F-35B [4]	58%	71%	42%	16
Lemoore F-35C [4]	54%	92%	18%	8
Nevatim F-35A [5]	45%	45%	45%	7

Footnotes
1. Data represent fielded aircraft and do not include SDD test aircraft.
2. Aircraft assigned at the end of September 2017.
3. Amendola F-35A operations began December 2016.
4. Iwakuni F-35B, and Lemoore F-35C operations began January 2017.
5. Nevatim F-35A operations began September 2017.

- To account for the performance of the aircraft that are in the field and not in Depot status, the program tracks Mission Capable (MC) and Fully Mission Capable (FMC) rates. The MC rate indicates the proportion of all fielded aircraft not in depot that are capable of flying at least one mission of the F-35 mission set, while the FMC rate reports the proportion that can fly all defined F-35 missions. Both the fleet-wide and variant-specific rates for MC and FMC appeared stable.
  - The average monthly MC rate was 58 percent, ranging from 56 to 64 percent, with the F-35A achieving 59 percent, the F-35B at 54 percent, and the F-35C at 63 percent.
  - The average monthly FMC rate was 26 percent, ranging from 21 to 31 percent. This was for a fleet almost entirely in the Block 2B/3i configuration; the fleet did not yet have any aircraft in the Block 3F "full warfighting" configuration. The F-35A FMC rate of 34 percent was significantly higher than other variants, with the F-35B at 14 percent and the F-35C at 15 percent.
- The average monthly utilization rate measures flight hours per aircraft per month. The utilization rate was 16.5 flight hours, reflecting the stable but low availability rate. The F-35A fleet averaged 18.0 flight hours, while the F-35B and F-35C fleets averaged 14.1 and 15.1, respectively.
  - The utilization rate has been relatively constant; the overall rate is similar to the average monthly utilization rate of 16.8 flight hours reported in the FY16 DOT&E Annual Report.
- The stagnant availability and utilization rates continue to prevent the Services from achieving their programmed fly rates, which are the basis of flying hour projections and sustainment cost models. As of April 3, 2017, the fleet had flown 72,019 hours. This amounted to 71 percent of the roughly estimated 100,800 hours from the original beddown plan the Services originally programmed for, or 84 percent of the most recent "modeled achievable" 85,882 flight hours.
- To help increase aircraft availability rates and reduce time waiting for spare parts, the program, in coordination with the Services, should stand up intermediate-level maintenance capability as soon as possible, particularly to support deployed aircraft and ship-borne operations.
- A separate analysis of availability of the OT-instrumented fleet, using data from the 12-month period ending September 2017, is important to consider as the program prepares for IOT&E. This analysis shows similar availability for the F-35A, but less availability for the F-35B and F-35C. The numbers below account only for the aircraft assigned to the OT fleet at the end of September 2017 (8 F-35A, 7 F-35B, 7 F-35C). There was little change in the availability trend of the F-35B and F-35C OT fleets.
  - The average monthly availability rate for F-35A OT aircraft was 51 percent, ranging from 13 to 70 percent. F-35A OT aircraft achieved or exceeded 60 percent availability at the beginning of the period. Availability declined precipitously from June 2017, reaching 13 percent in September 2017. This was primarily due to the Distributed Aperture Sensor (DAS) windows. The program established damage limits for the DAS windows in summer 2017, leading to closer inspections and a fleet-wide surge of demand for replacements for damaged windows. Although the aircraft with damaged windows are airworthy, they are not FMC. In fact, the Air Force does not report them as mission capable at all; but rather NMC-A, or Non-Mission Capable for Low Observable capabilities. Alternatively, the Department of the Navy reports such aircraft as PMC.
  - The average monthly availability rate for F-35B OT aircraft was 35 percent, ranging from 18 to 58 percent.

- The average monthly availability rate for F-35C OT aircraft was 41 percent, ranging from 28 to 73 percent. Ongoing modifications of the F-35C fleet affected availability during this period.
- Because the OT aircraft were produced in earlier production lots, they require many modifications to be production-representative of the Block 3F aircraft being delivered in Lot 9. Although later-lot aircraft have shown higher availability rates, they are still well below the planned 80 percent availability needed to efficiently execute IOT&E, especially for consistently launching variant-specific four-ship flights for many of the mission trials.

- F-35 Fleet Reliability
  - Aircraft reliability assessments include a variety of metrics, each characterizing a unique aspect of overall weapon system reliability.
    - Mean Flight Hours Between Critical Failure (MFHBCF) includes all failures that render the aircraft unsafe to fly, along with any equipment failures that would prevent the completion of a defined F-35 mission. It includes failures discovered in the air and on the ground.
    - Mean Flight Hours Between Removal (MFHBR) indicates the degree of necessary logistical support and is frequently used in determining associated costs. It includes any removal of an item from the aircraft for replacement. Not all removals are failures; some removed items are later determined to have not failed when tested at the repair site, and other components can be removed due to excessive signs of wear before a failure, such as worn tires.
    - Mean Flight Hours Between Maintenance Event Unscheduled (MFHBME_Unsch) is a reliability metric for evaluating maintenance workload due to unplanned maintenance. Maintenance events are either scheduled (e.g., inspections or planned part replacements) or unscheduled (e.g., failure remedies, troubleshooting, replacing worn parts such as tires). MFHBME_Unsch is an indicator of aircraft reliability and must meet the ORD requirement.
    - Mean Flight Hours Between Failure, Design Controllable (MFHBF_DC) includes failures of components due to design flaws under the purview of the contractor, such as the inability to withstand loads encountered in normal operation.
  - The F-35 program developed reliability growth projection curves for each variant throughout the development period as a function of accumulated flight hours. These projections compare observed reliability with target numbers to meet the threshold requirement at maturity (200,000 total F-35 fleet flight hours, made up of 75,000 flight hours each for the F-35A and F-35B, and 50,000 flight hours for the F-35C). As of May 31, 2017, the date of the most recent set of reliability data available, the fleet and each variant accumulated the following flight hours, with the percentage of the associated hour count at maturity indicated as well:
    - The complete F-35 fleet accumulated 86,233 flight hours, or 43 percent of its maturity value.
    - The F-35A accumulated 48,752 hours, or 65 percent of its maturity value.
    - The F-35B accumulated 26,374 hours, or 35 percent of its maturity value.
    - The F-35C accumulated 11,107 hours, or 22 percent of its maturity value.
  - The program reports reliability and maintainability metrics for the three most recent months of data. This rolling 3-month window dampens month-to-month variability while providing a short enough period to distinguish current trends.
  - The following tables for MFHBCF, MFHBR, MFHBME_Unsch, and MFHBF_DC compare the most recently reported and projected interim goal values with associated flight hours. July 2016 values (used in the FY16 DOT&E Annual Report) are included for reference. The tables also include projected values for each ORD metric at maturity, based on updated reliability growth analyses through May 2017.

F-35 RELIABILITY: MFHBCF (HOURS)

Variant	ORD Threshold		Values as of May 31, 2017					Values as of July 2016	
	Flight Hours	MFHBCF	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBCF	Observed MFHBCF (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Reliability Growth Projection at Maturity	Cumulative Flight Hours	Observed MFHBCF (3 Mos. Rolling Window)
F-35A	75,000	20	48,752	18.8	8.0	43%	8.5	32,358	8.0
F-35B	75,000	12	26,374	10.4	4.6	44%	N/A	20,256	4.6
F-35C	50,000	14	11,107	11.5	8.0	70%	N/A	7,648	4.2

F-35 RELIABILITY: MFHBR (HOURS)									
Variant	ORD Threshold		Values as of May 31, 2017					Values as of July 2016	
	Flight Hours	MFHBR	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBR	Observed MFHBR (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Reliability Growth Projection at Maturity	Cumulative Flight Hours	Observed MFHBR (3 Mos. Rolling Window)
F-35A	75,000	6.5	48,752	6.1	4.9	80%	5.3	32,358	4.7
F-35B	75,000	6.0	26,374	5.2	2.9	56%	3.8	20,256	2.8
F-35C	50,000	6.0	11,107	4.9	3.7	76%	N/A	7,648	2.3

F-35 RELIABILITY: MFHBME (HOURS)									
Variant	ORD Threshold		Values as of May 31, 2017					Values as of July 2016	
	Flight Hours	MFHBME	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBME	Observed MFHBME (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Reliability Growth Projection at Maturity	Cumulative Flight Hours	Observed MFHBME (3 Mos. Rolling Window)
F-35A	75,000	2.0	48,752	1.88	1.56	83%	1.54	32,358	1.36
F-35B	75,000	1.5	26,374	1.30	1.03	79%	1.75	20,256	1.08
F-35C	50,000	1.5	11,107	1.20	0.83	69%	1.14	7,648	0.74

F-35 RELIABILITY: MFHBF_DC (HOURS)								
Variant	JSF Contract Specification Requirement		Values as of May 31, 2017				Values as of July 2016	
	Flight Hours	MFHBF_DC	Cumulative Flight Hours	Interim Goal to Meet Threshold MFHBF_DC	Observed MFHBF_DC (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBF_DC (3 Mos. Rolling Window)
F-35A	75,000	6.0	48,752	5.57	6.1	110%	32,358	5.8
F-35B	75,000	4.0	26,374	3.37	3.8	113%	20,256	4.1
F-35C	50,000	4.0	11,107	3.12	5.0	160%	7,648	3.3
MFHBF_DC is a contract specification, so its JSF contract specification requirement is shown in lieu of an ORD threshold. Since this measure does not have an ORD requirement, no "reliability growth projection at maturity" was computed.								

- Overall F-35 reliability has changed little compared to July 2016. Most changes are nominal and within the natural variability of 3-month moving averages for the F-35. The exceptions are F-35A MFHBME, F-35C MFHBCF, and F-35C MFHBR reliability metrics; all three of these ORD reliability metrics show improvement over the past year. Nonetheless, all ORD reliability metrics for all variants fall short of their interim goals.
- Later production lot aircraft have tended to have higher reliability values than earlier lot aircraft. An analysis of MFHBR values by lot showed a significant increase in reliability for F-35A aircraft for Lots 6 and later compared to aircraft from Lots 5 and earlier. However, most aircraft within F-35A Lots 6 and later had similar reliability values. This lot-by-lot improvement trend was much less pronounced for the F-35B variant. The F-35C was not investigated due to the small number of aircraft in the fleet, and thus very small numbers of F-35C in each lot, making statistically significant evaluation difficult.
- The program should review reliability and maintenance data from test and operations and provide an updated sustainment cost estimate based on actual data and trends. This updated estimate should include assessments of sustaining aircraft in older configurations vice modifying them to current configurations.
- In addition to reporting the MFHBCF values above, the JPO has recently adopted a second, alternative approach for reporting MFHBCF which only counts critical failures that take 8 hours or more to remedy. This approach presumably supports modeling of Sortie Generation Rate (SGR), a Key Performance Parameter in the ORD.
  - Based on recent data sets, this alternative approach does not account for approximately three quarters of all critical failures, resulting in a higher MFHBCF estimate. For example, for the 3 months ending in April 2017, the JPO reports the F-35A MFHBCF rate using this alternate approach as 27.4 hours versus 7.7 hours when counting all critical failures; the F-35B MFHBCF rate

as 17.2 hours versus 4.6 hours when counting all critical failures; and the F-35C MFHBCF rate as 35.6 hours versus 8.5 hours.
    - DOT&E disagrees with this approach because failures that take less than 8 hours to remedy can still affect SGR. Also, it is not consistent with the widely accepted definition of the MFHBCF measure.
- F-35 Reliability Growth
  - DOT&E updated a reliability growth analysis from the FY16 Annual Report, based on the Army Materiel Systems Analysis Activity (AMSAA)-Crow Projection Model and using cumulative flight hour and failure data from the start of flying for each variant through May 2017. The AMSAA-Crow model is used to estimate system reliability and is able to project the impact of corrective actions on system reliability.
  - This updated, long-term analysis shows flat or negative reliability growth for F-35B MFHBCF, F-35C MFHBCF, and F-35C MFHBR. Although both F-35C MFHBCF and MFHBR have improved over the last year, they have not improved enough to overcome the trend based on historical data from prior years. As a result, these three metrics have no projection at maturity. Sustained improvement is needed for positive reliability growth to become apparent in future long-term analyses.
  - For the remaining six ORD metrics, only one, F-35B MFHBME, is on track to surpass its threshold requirement by maturity.
- Maintainability
  - The amount of time needed to repair aircraft and return them to flying status has changed little over the past year, but remains higher than the requirement for the system when mature. The program assesses this time with several measures, including Mean Corrective Maintenance Time for Critical Failures (MCMTCF) and Mean Time To Repair (MTTR) for all unscheduled maintenance. Both measures include "active touch" labor time and cure times for coatings, sealants, paints, etc., but do not include logistics delay times, such as how long it takes to receive shipment of a replacement part.
    - MCMTCF measures active maintenance time to correct only the subset of failures that prevent the F-35 from being able to perform a specific mission. It indicates the average time for maintainers to return an aircraft from NMC to MC status.
    - MTTR measures the average active maintenance time for all unscheduled maintenance actions. It is a general indicator of the ease and timeliness of repair.
  - The program reports maintainability metrics for the three most recent months of data. The tables provide MCMTCF and MTTR values for the 3-month period ending May 31, 2017, the date of the most recent maintainability report available, and compare those values to the ORD threshold.
    - All mean repair times are longer, some up to more than twice as long, as their ORD threshold values for maturity, reflecting a heavy maintenance burden on fielded units.
    - July 2016 values used in the FY16 DOT&E Annual Report are included for reference. No significant change or trend can be determined between data from July 2016 to May 2017.

F-35 MAINTAINABILITY: MCMTCF (HOURS)				
Variant	ORD Threshold	Values as of May 31, 2017 (3 Mos. Rolling Window)	Observed Value as Percent of Threshold	Values as of July 2016 (3 Mos. Rolling Window)
F-35A	4.0	12.3	308%	10.6
F-35B	4.5	11.9	264%	13.2
F-35C	4.0	11.7	293%	10.1

F-35 MAINTAINABILITY: MTTR (HOURS)				
Variant	ORD Threshold	Values as of May 31, 2017 (3 Mos. Rolling Window)	Observed Value as Percent of Threshold	Values as of July 2016 (3 Mos. Rolling Window)
F-35A	2.5	7.4	296%	6.3
F-35B	3.0	7.7	257%	7.3
F-35C	2.5	4.7	188%	4.9

  - The JPO, after analyzing MTTR projections to maturity, acknowledged that the program would not meet the MTTR requirements defined in the ORD. The JPO is seeking relief from the original MTTR requirements and has proposed new values of 5.0 hours for both the F-35A and F-35C, and 6.4 hours for the F-35B. This will affect the ability to meet the ORD requirement for Sortie Generation Rate (SGR), a Key Performance Parameter.
  - The amount of time spent maintaining the low observable (LO) properties of the aircraft, particularly those repairs involving cure times with the LO coatings and seals, is greater than requirements, but an improvement over earlier generations of LO aircraft. The MTTR for LO-related maintenance events was 12.4 hours for the F-35A, 17.1 hours for the F-35B, and 14.7 for the F-35C. These metrics are based on maintenance data from March 2012 through February 2017. Higher-than-planned replacement rates for blade seals (designed to cover gaps between structural surfaces), canopy boots and wingtip light lens covers have contributed to extend LO repair times. Improved versions of these components have been designed with anticipated lower failure rates, and should lower the overall LO maintenance burden in the fleet once incorporated. The improved versions have not yet proliferated to all fielded aircraft. In CY17, the Air Force created a new reporting status, designated NMC-A, for tracking aircraft that are NMC due to excessive degradation of LO capabilities, and asked the JPO to track this category for fleet metrics. This status is based on the rating provided by the Low Observable Health Assessment

System (LOHAS) module of ALIS, where the LO status of the aircraft is assessed and tracked based on LO defects and LO maintenance activity completed.

- Air-Ship Integration and Ship Suitability Testing
  - Dawn Blitz, a large combined Navy-Marine Corps exercise, included F-35B aircraft flying from the USS *Essex* off the coast of Southern California. The exercise ran from October 20-30, 2017, but full analysis of all collected data was not complete at the time of writing this report. However, DOT&E personnel on the USS *Essex* made three significant observations:
    - Initial aircraft reliability and availability were immediately problematic, with 7 of 8 planned aircraft arriving and only 3 of 7 available to fly by the second day of flying. Although the aircraft completed most of their planned missions, usually consisting of a four-aircraft requirement, it would have been challenging to achieve equal success with only six aircraft, as normally assigned, and with a longer logistics burden, as would be the case in a deployed theater.
    - The ship's electrical power, from wall outlets in the hangar bay and on the flight deck used for aircraft maintenance, appeared to damage electrical components in two of the aircraft. This damage made the aircraft NMC on day two of the exercise. From that day forward, maintainers only applied power to aircraft using F-35 specific Support Equipment (SE).
    - The F-35 has large, unique SE that is not compatible with the common SE for the other aircraft on the USS *Essex*. As a result, large areas of the hangar deck were taken up by the two sets of SE, which may make it difficult to efficiently conduct maintenance with a full complement of aircraft onboard for an actual deployment.

Autonomic Logistics Information System (ALIS)

ALIS Activity

- ALIS 2.0.2.4 was originally scheduled for release in 2016, but delays in development pushed the initial fielding into 2017.
- The program focused on testing and fielding ALIS software version 2.0.2.4 throughout CY17. Testing included the following new major capabilities:
  - Life Limited Parts Management, which includes propulsion data integration and Production Aircraft Inspection Requirements (PAIRs). PAIRS includes the first eight prognostics-based algorithms for the program.
  - Sub-squadron reporting, which relays the status of detached aircraft back to the home squadron Standard Operating Unit (SOU).
  - Limited direct SOU-to-SOU communications, to improve deployed operations.
  - Deployment planning tool.
- The program conducted initial testing of ALIS 2.0.2.4 with field data at two venues.
  - Testing with OT aircraft occurred on the Operationally Representative Environment (ORE) at Edwards AFB from February 1-24, 2017. The ORE consists of production-representative ALIS hardware in a closed network. This venue is designed for testing ALIS software using data downloaded from OT aircraft.
  - Testing with SDD aircraft occurred at the Air Force Test Center at Edwards AFB from February 7-24, 2017.
  - Because of limitations associated with the hardware versions of the ALIS equipment used to support the SDD aircraft and the ORE, the program could not conduct complete operationally representative testing of new ALIS software versions in either venue.
- The program completed verification testing of ALIS 2.0.2.4 at Nellis AFB. This testing showed that the migration to ALIS 2.0.2.4 at the fielded units would require an extensive effort to ensure that all the data for the aircraft, propulsion systems, spare parts, and support equipment migrated accurately into the more restrictive data structures within ALIS 2.0.2.4.
  - The program allocated 2 weeks for each operating site to complete the migration in an attempt to minimize the effect on flying operations, projecting 8 months to complete all units.
  - After four sites completed migration, VMFA-211, one of the two operational F-35B units at MCAS Yuma, discovered that ALIS was not properly tracking life usage on engine components and suspended flying operations in June 2017.
  - The program ceased migration of remaining sites to ALIS 2.0.2.4 in order to identify root causes and corrective actions and then developed and tested software fixes in another version of ALIS software – version 2.0.2.4.4.
- The program conducted initial testing of ALIS 2.0.2.4.4 on the ORE at Edwards AFB. Validation testing occurred at MCAS Yuma in September 2017.
  - Based on the late discovery of problems at MCAS Yuma, the Air Force required ALIS 2.0.2.4.4 to undergo further testing at Nellis AFB before allowing fielding to other Air Force sites.
  - Deficiencies discovered during the testing of ALIS 2.0.2.4.4 at Nellis AFB in September 2017 required the program to make more software corrections before the Air Force would permit fielding to operational units proceed.
  - The Air Force restarted fielding ALIS 2.0.2.4.4 at Eglin AFB, Florida, in November 2017, to be followed by Luke AFB, Arizona, in January 2018.
- The program expected to begin testing ALIS 2.0.2.5 in October 2017 at the Air Force Test Center at Edwards AFB, and expects to field this update in December 2017. ALIS 2.0.2.5 is intended to address deficiencies and usability problems, upgrade the browser to Internet Explorer 11, and include a filtering function to decrease false alarms in the

Prognostic Health Management (PHM) System. It will include no other new capabilities.
- ALIS 3.0 began regression testing at the Lockheed Martin facility in Orlando, Florida. Major new capabilities include support for lightning protection, improvements to the LOHAS, security enhancements, an initial parts identification and location (IDLO) capability, and corrections to existing deficiencies. The IDLO capability is intended to facilitate maintaining the aircraft which usually have a unique "as maintained" configuration due to the concurrency of production and development and the complex modification program.

ALIS Assessment
- ALIS is designed to bring efficiency to maintenance and flight operations, but it does not yet perform as intended due to several unresolved deficiencies. For example:
  - Most capabilities function as intended only with a high level of manual effort by ALIS administrators and maintenance personnel. Manual work-arounds are often needed to complete tasks designed to be automated. Maintainers frequently must manually enter missing or incorrect Electronic Equipment Logbook data, which accompany spare parts, so they can be accepted and tracked by an SOU.
  - Configuration management of ALIS software and data products remains complex and time-consuming.
  - ALIS incorrectly reports the status of aircraft as Not Mission Capable in the Squadron Health Management application based on Health Reporting (fault) Codes. Meanwhile, a separate application – Customer Maintenance Management System, which relies on the Mission Essential Function List (MEFL) – reports the same aircraft as mission capable. A logistics test and evaluation report for ALIS version 1.0.3A3 in December 2012 first noted this problem.
- Initial testing of ALIS 2.0.2.4 uncovered deficiencies requiring corrections. The Air Force Test Center recommended that the program field ALIS 2.0.2.4 after developing software fixes for the most serious deficiencies. Validation testing demonstrated no problems beyond those noted at the ORE and logistics test and evaluation.
- ALIS 2.0.2.4 does not address many unresolved deficiencies and the program has not yet allocated an appropriate level of funding in SDD to resolve them. The existing unresolved deficiencies will continue to negatively affect aircraft availability and sortie generation rate. The program does not have sufficient resources to simultaneously develop new required capabilities and reduce unresolved deficiencies.
- The ALIS 2.0.2.4.4 validation testing at MCAS Yuma discovered problems related to propulsion data management and life usage tracking. Smaller problems with Portable Maintenance Aid synchronization and the transfer of air vehicle data between SOUs were also discovered. Testing showed improved Portable Memory Device download times compared to earlier versions of ALIS software.
- The program deferred many of the remaining planned capabilities for SDD out of ALIS 3.0. Despite these deferrals, the schedule for ALIS 3.0 is at risk. Delays associated with completing and testing ALIS 2.0.2.4 have contributed to this risk.
  - In late July 2017, the program noted that if ALIS 2.0.2.4.4 was not in flight test by the end of September 2017, the ALIS 3.0 flight test would not occur until 2018. ALIS 2.0.2.4.4 did undergo flight test before the end of September 2017, but the program found deficiencies that were addressed before fielding to operational units resumed in November 2017. As of the end of September 2017, the program had not allocated funding for the rollout of ALIS 3.0 nor made plans for the migration.
  - Resource availability will continue to affect the ALIS 3.0 schedule and will likely affect the schedule and fielding of ALIS 4.0, which has most of the remaining capabilities planned for SDD. The program noted in September 2017 that the margin built into the ALIS development and release schedule will not be sufficient to cover the delays already projected, so the ALIS 4.0 schedule is high risk.
  - It is unlikely that ALIS 3.0 will be fielded and available for use in any carrier deployments planned for IOT&E.
- Assessment of the testing regimen for ALIS.
  - The program relies too heavily on the results of laboratory testing of ALIS software, which does not resemble operational conditions in several ways, including the amount of data processed and external connections. This non-operationally representative method of testing leads to delays in finding and fixing deficiencies, often after the software is fielded. The program should develop an adequate ALIS test venue to ensure ALIS capabilities are well-tested prior to fielding to operational units.
  - The investigation into shortcomings in the conduct of ALIS 2.0.2.4 testing showed that fleet personnel used ALIS in ways that laboratory testers did not.
  - Developmental testing should include the use of a variety of personnel from different Services and experience levels to increase the chances of finding problems early.
  - ALIS testing, architecture, operation, and fielding each absorb a disproportionate amount of time, manpower, and funding.

Prognostic Health Management
- The program developed and is testing an Advanced Filter and Correlate (AFC) 1.0 capability, which is part of the PHM System. AFC 1.0 is intended to mitigate:
  - The number of false alarm Health Reporting Codes (HRCs)
  - Sympathetic HRCs, which result in a single failure generating multiple HRC Work Orders
  - Conditional nuisance HRCs, which are false alarms triggered only by certain, non-operationally representative aircraft configurations, such as test aircraft or aircraft

maintained in a unique configuration (i.e., caused by the concurrency of production and development)
- ALIS 2.0.2.4 includes the first seven prognostic algorithms in PHM which involve monitoring of fuel, oil, and hydraulic fluid. The personnel who initially use these algorithms will collect data that will be used to mature the servicing and remaining life predictions.
- The program moved from reporting PHM metric performance in 6-month rolling windows to 3-month rolling windows. The following table shows the most recent data available. Compared to last year's Annual Report, nearly every fault detection and isolation metric has improved for both Block 2B and 3F with the exception of the two non-electronic fault isolation metrics for Block 3F, which decreased 7 to 9 percent.
- PHM diagnostic performance shows improvement overall with two of five metrics meeting threshold requirements in this rolling window. DOT&E will need more formally adjudicated data before determining if PHM maturation is sufficient to meet any of its threshold requirements.
- The small improvements in false alarm metrics noted in the last three Annual Reports indicate the program will not meet false alarm threshold requirements. The program expects AFC 1.0 to improve PHM false alarm performance, but DOT&E estimates the improvements will be insufficient for the program to meet requirements.

METRICS OF DIAGNOSTIC CAPABILITY
(3-month rolling window, as of February 2017. Data provided by the F-35 Joint Program Office are preliminary; they have not completed the formal adjudication by the data review board.)

Diagnostic Measure	Threshold Requirement	Demonstrated Performance	
		Block 2B	Block 3F
Developmental Test and Production Aircraft			
Fault Detection Coverage (percent mission critical failures detectable by PHM)	N/A	90	96
Fault Detection Rate (percent correct detections for detectable failures)	98	90	96
Fault Isolation Rate (percentage): Electronic Fault to One Line Replaceable Component (LRC)	90	84	75
Fault Isolation Rate (percentage): Non-Electronic Fault to One LRC	70	83	77
Fault Isolation Rate (percentage): Non-Electronic Fault to Three or Fewer LRC	90	92	92
Production Aircraft Only			
Mean Flight Hours Between False Alarms	50	0.71	1,03 [1]
Mean Flight Hours Between Flight Safety Critical False Alarms	450	878	430 [1]
Accumulated Flight Hours for Measures	N/A	2,634	430 [1]
Ratio of False Alarms to Valid Maintenance Events	N/A	14:1	33:1 [1]

1. False alarm activity may be underreported due to flight test activity (i.e., the control room may be able to tell the pilot that a fault indication is a false alarm that would otherwise have been reported in the field)

Cybersecurity Operational Testing

Activity

- The JOTT continued to accomplish testing based on the cybersecurity strategy, approved by DOT&E in February 2015, with some modifications due to test limitations. The JOTT assessed the Autonomic Logistics Information System (ALIS) version 2.0.2.4 at all three levels of operation:
  - Autonomic Logistics Operating Unit (ALOU)
  - Central Point of Entry (CPE)
  - Squadron Kit (SQK), comprised of the Standard Operating Unit (SOU), the Mission Planning and Support Boundary (MPSB), and the Low Observable Maintenance Boundary (LOMB)
- In 2017, the JOTT conducted Cooperative Vulnerability and Penetration Assessments (CVPAs) of ALIS 2.0.2.4 at three locations in partnership with certified cybersecurity test organizations and personnel:
  - The Navy's Operational Test and Evaluation Force cyber testers assessed the ALOU at Lockheed Martin, Fort Worth, Texas.
    - Unanticipated DOD policy changes for classified equipment security requirements prevented any testing of the classified segment of the ALOU.
  - The 92nd Cyber Operations Squadron assessed the CPE at Eglin AFB and assessed the SQK at Edwards AFB.
    - Unanticipated changes in classified equipment security requirements based on a new DOD policy memorandum disrupted the pace of cyber testing on the SQK.
    - Edwards AFB had not yet received the most recent version of the Low Observable Health Assessment System (LOHAS) workstation and the JOTT decided not to test the available, non-operationally representative older system. The JOTT only became aware of this limitation onsite during the test. The JOTT still tested the operationally representative LOHAS server.
    - Administrative delays with the SOU, caused by pre-coordination problems with the contractors who administer the Edwards SOU, reduced the time available for penetration testing.
- In 2017, the JOTT conducted Adversarial Assessments (AAs) of ALIS 2.0.2.4 at three locations in partnership with certified cybersecurity test organizations and personnel. The AAs did not conclude as originally planned because U.S. Cyber Command (USCYBERCOM) issued and subsequently extended a Period of Non-Disruption (POND), directing all DOD Red Teams to halt activities during the last week of the planned test period.
  - The Marine Corps Information Assurance Red Team (MCIART) assessed the ALOU at Lockheed Martin, Fort Worth.
    - MCIART completed testing of the unclassified ALOU; however, it did not test the classified ALOU due to the USCYBERCOM POND direction to temporarily cease AA testing.
  - The 57th Information Aggressor Squadron (IAS) assessed the CPE at Eglin AFB.
    - As a result of the USCYBERCOM POND, the 57th IAS did not conduct an AA against the classified CPE.
    - The test team also did not complete its assessment of the unclassified CPE.
    - The Eglin AFB unit commander approved a white card physical access assessment of the CPE, which consisted of 57th IAS personnel holding a guided discussion with key CPE personnel.
  - The 177th IAS assessed the SQK at Hill AFB, Utah.
    - The 177th IAS completed testing of the SOU and the MPSB.
    - Due to the USCYBERCOM POND, the test team did not conduct an AA against the LOMB.
    - The Hill AFB unit commander declined permission to undertake the planned close access team assessment of the SQK.
- In response to the DOT&E recommendation to conduct active intrusion discovery and forensics, referred to as a Blue Hunt, on ALIS, the JOTT has scheduled Blue Hunt events for SQK, CPE, and ALOU in CY18.
- Due to the USCYBERCOM POND guidance, full end-to-end cybersecurity testing of the ALIS architecture, from the operational ALOU to the air vehicle, which was planned for 2017, remains to be completed. The JOTT is planning assessments of ALIS 3.0, the air vehicle, the Full Mission Simulator (FMS), the U.S. Reprogramming Laboratory (USRL), and the Operationally Representative Environment (ORE) in 2018 as part of IOT&E. The JOTT is also exploring testing opportunities to complete portions of the AA not undertaken or partially completed.

Assessment

- Cybersecurity testing in 2017 showed that some of the vulnerabilities identified during earlier testing periods still had not been remedied.
- More testing is needed to assess the cybersecurity structure of the air vehicle and supporting logistics infrastructure system (i.e., ALOU, CPE, SQK) and to determine whether, and to what extent, vulnerabilities may have led to compromises of F-35 data. The JOTT has scheduled this testing in CY18.
- The JOTT should expand the scope of cybersecurity testing to include fielded aircraft and other systems required to support the fielded aircraft, such as the Multifunction Analyzer Transmitter Receiver Interface Exerciser (MATRIX). MATRIX is a troubleshooting computer system used by contractor maintenance technicians to detect and isolate faults and is more capable than the Portable Maintenance Aid used by Service maintenance personnel.
- The program should fully complete end-to-end cybersecurity testing on all three levels of ALIS for each of the planned updates to ALIS software and all other systems associated

with the F-35 program, including the USRL, software integration labs, MATRIX, etc.
- Testing to date has identified vulnerabilities that must be addressed to ensure secure ALIS operations. The program should immediately address all identified cyber vulnerabilities from previous rounds of cybersecurity testing.
- According to the JPO, the air vehicle is capable of operating for up to 30 days without connectivity to ALIS. In light of current cybersecurity threats and vulnerabilities, along with peer and near-peer threats to bases and communications, the F-35 program and Services should conduct testing of aircraft operations without access to ALIS for extended periods of time.

IOT&E Readiness

The JPO, Lockheed Martin, and JOTT continued to make preparations for IOT&E. Despite significant effort and progress since the FY16 DOT&E Annual Report, the readiness criteria will not be met until late CY18 to allow formal IOT&E to start. Besides the delays in completing development, producing a verified MDL, and completing ALIS 3.0 development and fielding, this section addresses additional challenges the program must overcome to ensure IOT&E readiness.

Aircraft modifications
- Up to 155 modifications per aircraft are required to bring the early lot OT aircraft into the production-representative configuration required for IOT&E.
- Despite a significant effort by the JPO, JOTT, and Lockheed Martin to minimize delays, modification to all of the 23 IOT&E aircraft will not be complete until August 2018, at the soonest. This challenge is further complicated because some of the IOT&E aircraft were loaned for use by DT, delaying the start of their modification process until their work assisting DT is complete.

Instrumentation
- Test instrumentation requirements will likely not be met until integration and testing is complete in the third quarter of CY18.
- Air-to-Air Range Infrastructure system, version 2 (AARI 2) is undergoing integration and testing with the F-35 aircraft and mission systems software. It is required for mission test trials on the Nevada Test and Training Range (NTTR).
- The Data Acquisition Recording and Telemetry (DART) pod must be certified to the same flight envelope as the internal weapons are for Block 3F, including weapons bay door opening during simulated weapon launches.
- Air Warfare Battle Shaping (AWBS), which can host AARI 2 on the Navy's Pacific Sea Test Range (STR) and China Lake test range, must complete integration and testing to support mission test trials.
- Integration and testing of range threat emitters, which will be used on both the NTTR and STR, must be complete before they can support open air mission trials.

Joint Simulation Environment
- The Joint Simulation Environment (JSE) is a man-in-the-loop simulator. It runs the F-35 operational flight program (mission systems software) and is intended for use in IOT&E to conduct scenarios with modern threat types and densities that are not able to be replicated in open air. Originally slated to be operational by the end of 2017, delivery of the JSE is now planned for late 2018 with accreditation in 2019, near the end of planned IOT&E trials.
- Development of the JSE, although late, made good progress this year with one exception: Integration of the critical F-35 model has lagged behind the development of other parts of the simulation due to contractual difficulties. Until resolved, this problem will continue to increase the risk to delivering the JSE in time for use as an IOT&E venue.
- The JSE's physical facilities (cockpits, visuals, and buildings) and synthetic environment (terrain, threat, and target models) are nearing completion. The JSE version 0.5 configuration included most of the necessary environment, but not the F-35 model, and was successfully delivered in early October 2017, passing all verification testing.
- The JSE validation process has continued to lag development and is now the schedule driver for successful delivery of the simulation. Contractual problems, the lack of a working F-35 simulation, and an inability to harvest needed reference data from the F-35 flight test effort have all contributed to continuing delays in validation and hence accreditation for use in IOT&E.
- Successful completion of the F-35 model contract and increased productivity of the validation team may lead to a usable resource for IOT&E, but both are extremely high risk. The JOTT, per DOT&E direction, continues to plan to execute IOT&E without this resource. However, if the JSE becomes ready and accredited in time, it will be used during IOT&E. Without the JSE, the IOT&E will be limited in assessing the F-35 against complex threats, resulting in risk for operational use. If still not completed by the time IOT&E ends, the JSE should be a valuable test resource for follow-on F-35 testing and possibly for testing of other platforms.

Unresolved Technical Deficiencies
- Deficiency Reporting and Fix Prioritization
  - The JPO, Services, and operational test units continued the process of sorting, adjudicating by severity, and coordinating the hardware and software fixes needed to resolve the backlog of open and newly discovered deficiencies. This effort supports the JSF contract specification verification process the program must complete to finish SDD, the readiness criteria to enter IOT&E, and the delivery of the combat capability required by the Services and partner nations.
  - As of mid-November 2017, the JSF development program was monitoring a total of 2,769 deficiency reports.

Of these, 1,748 have been closed via the review processes now in place. To meet "closure" criteria, these deficiency reports were either determined to no longer be relevant (i.e., they originated in older software versions), or they were deferred to follow-on development (C2D2), corrected and verified, or combined with other relevant deficiency reports. An additional 29 deficiency reports were canceled. The Services and JOTT have reviewed the remaining 992 active deficiency reports for operational effects and meeting readiness criteria for beginning IOT&E. This review created a Service priority list of 301 Priority 1 and 2 deficiencies deemed necessary for the program to address for combat effectiveness and operational testing. However, only 88 of the 301 Priority 1 and 2 deficiencies were in-work, with the remaining 213 unresolved. These deficiencies must either be corrected or have Service-approved, operationally acceptable work-arounds. These deficiencies affect target kill chains, weapons integration, combat survivability, shipboard operations, maintenance/operational documentation, mission planning, ALIS functionality, operational test instrumentation, and cybersecurity.

- Pilot Escape System
  - In May 2017, the Air Force and Navy announced that they were lifting restrictions on lightweight pilots flying F-35s because the fixes that were put in place to address ejection seat problems were working.
  - The JPO provided DOT&E with the F-35 System Safety Risk Assessment (SSRA) it conducted on the additional risk-reducing actions to the pilot escape system during recent testing. The JPO SSRA was informed by modeling and simulation of ejections in off-nominal conditions, along with limited ground subsystem testing with a manikin and the Head Support Panel (HSP), to assess the overall risk of injury as "Low." The testing showed that the changes incorporated into the seat and provided to the pilot's equipment have generally reduced the risk of neck injury to the pilot under the normal ejection conditions.
  - The JPO also provided DOT&E with an SSRA supplement from the U.S. Air Force Technical Airworthiness Authorities (TAA). In that document, due to a lack of test data in off-nominal conditions, the TAA assessed that the level of risk of injury to lighter-weight pilots (103 to 135 pounds with the Gen III Lite helmet, and 136 to 150 pounds with any Gen II/III/III Lite helmet) was categorized as "Serious" due to the absence of test data with the new changes to the ejection system and the potential for head and neck injury during off-nominal ejections at airspeeds less than 190 knots. The TAA determined that it may be possible for the head to miss the HSP for these lighter weight pilots and the result could be either death or total disability. However, the risk was reduced sufficiently during the ejection testing in nominal conditions for the Air Force to remove the restriction preventing pilots weighing less than 136 pounds from flying the F-35.
  - The program began retrofitting fielded F-35s with the modifications to the ejection seats in 2017 and plans to deliver aircraft with the upgraded seat in Lot 10, starting in January 2018. The Gen III Lite helmets will be included with the Lot 10 aircraft delivery, and will be delivered starting in November 2017. If these delivery timelines are met, the Air Force may open F-35 pilot training to lighter-weight pilots (i.e., below 136 pounds) as early as December 2017.
  - Part of the weight reduction to the Gen III Lite HMDS involved removing one of the two visors (one dark, one clear). As a result, pilots that need to use both visors during a mission (e.g., during transitions from day to night), will have to store the second visor in the cockpit. However, there is no designated storage space in the cockpit for the visor; the program is working a solution to address this problem.
  - The program has yet to complete additional testing and analysis needed to determine the risk of pilots being harmed by the Transparency Removal System (TRS), which shatters the canopy first, allowing the seat and pilot to leave the aircraft) during ejections in other than ideal, stable conditions (such as after battle damage or during out-of-control situations). Although the program completed an off-nominal rocket sled test with the TRS in CY12, several aspects of the escape system have changed since then, including significant changes to the helmet, which warrant additional testing and analyses. DOT&E recommends the program complete these tests, in a variety of off-nominal conditions, as soon as possible, so that the Services can better assess risk associated with ejections under these conditions.
- Physiological Incidents
  - Multiple pilot physiological events were reported in 2017, with the majority of them from Luke AFB, Arizona. No common root cause has been identified. The program is investigating the possibility of onboard oxygen generation system (OBOGS) degradations in the fleet. At the time of this report, testing of a new algorithm to control the oxygen generator within the OBOGS was in progress at Wright Patterson AFB, Ohio.
- Production Line Quality Lapses
  - The program recently discovered corrosion in an F-35A at Hill AFB, possibly due to Lockheed Martin not properly treating fastener holes with primer after drilling during production. At the time of this report, the program was still investigating, but it appears to be a production line quality lapse which may affect all variants. In 2016, the program had a well-publicized quality lapse with insulation on fuel tubes within F-35A fuel tanks which required extensive, intrusive depot-level modifications to repair the affected aircraft.
  - F-35A and F-35C fuel valve couplings within the fuel system may require a one-time inspection. This problem appears to be another quality lapse.

- F-35B Tires
  - The program has struggled to find a tire for the F-35B that is strong enough for conventional high-speed landings, soft enough to cushion vertical landings, and still light enough for the existing aircraft structure. Average F-35B tire life is below 10 landings, well below the requirement for 25 conventional full-stop landings. The program is still working this problem, which will not be resolved within SDD.
- Night Vision Camera (NVC)
  - The NVC used with the Gen III helmet has several deficiencies, including inadequate acuity for low-illumination operations (i.e., during a cloudy night with no stars, moon, or cultural lighting). As a result, F-35B pilots were losing situational awareness during night landings on an aircraft carrier. At the time of this report, incremental software solutions had been demonstrated in the lab and were planned for flight test. Further improvement is dependent on improved imaging technology with a prototype expected in 2019.
- F-35B and F-35C Air Refueling Restrictions
  - Both variants use an air refueling probe which is designed with an intentional weak link to protect the probe. The probe tips are breaking too often, resulting in squadrons imposing restrictions on air refueling. The program is still investigating this problem.

Full Mission Simulator

- The program experienced delays developing and fielding the Block 3i Full Mission Simulator (FMS) (i.e., pilot training simulator), with Block 3i aircraft being delivered to most locations well prior to the Block 3i FMS. The Block 3i FMS delays, along with ongoing Block 3F flight test delays, are also delaying development of the Block 3F FMS.
- As a result, the program plans to field an interim "Block 3FR1" version of FMS software in 2018 with partial Block 3F functionality. The Block 3FR1 FMS is based on an earlier Block 3F software version (Block 3FR6.01), to support the pilots flying Block 3F aircraft which are already being delivered. The program then plans to release a "Block 3FR2" version, based on Block 3FR6.3, with full Block 3F functionality between late CY18 through CY19.
  - All versions of FMS software to date, including the Block 3F FMS, are based on Lockheed Martin mission data loads (MDL) which are intended for use in DT flight test, not for realistic operational training or combat.
  - The utility of the Block 3F FMS for IOT&E training will depend on operational MDLs, developed by the USRL, being integrated with the FMS virtual threat environment. The existing FMS software development and integration processes will take about 24 months to incorporate a USRL MDL, once it is available.
  - Based on the timelines above, the Block 3F FMS will not be available to support IOT&E training, even with partial functionality using the DT MDL. A version of Block 3F FMS software with a fielded USRL MDL will likely not be available until 2020.
  - As a result, IOT&E pilots will need to rely on available aircraft, along with the Verification Simulator and JSE, for Block 3F training and spin-up (i.e., test mission rehearsals). This will place a heavier demand on the IOT&E aircraft from late 2017 through most of 2018, at a time when many of the aircraft will be undergoing modifications to be production-representative.
  - The JPO plans to change the FMS architecture in C2D2 to decrease the long software development and integration timelines while enabling rapid incorporation of operational mission data for more realistic training and mission rehearsals.

Pre-IOT&E Events

- As the program and JOTT continue to prepare for IOT&E, early releases of Block 3F software and mission data (i.e., Level 3 MDL) may allow the OT squadrons to train and conduct some spin-up activities prior to meeting formal spin-up entrance criteria.
- The JOTT plans to conduct operationally representative Pre-IOT&E events (i.e., weapons delivery events, cold weather deployment). Prior to seeking DOT&E approval of these events, the JSF Program Executive Officer will certify that the program is ready for the specific event(s) and will coordinate with the Defense Acquisition Executive for authorization to accomplish them. These Pre-IOT&E events will not interfere with preparations (i.e., modifications and spin-up) for formal IOT&E entrance planned for later in CY18.
- DOT&E will observe the execution of the Pre-IOT&E events and assess whether each event was operationally representative and adequate to meet IOT&E requirements. This may allow the program to apply data from select Pre-IOT&E events toward formal IOT&E assessment.

Recommendations

- Status of Previous Recommendations. The program adequately addressed 4 of the 17 previous recommendations. The following recommendations remain valid:
  1. The program should complete all necessary Block 3F baseline test points. If the program uses test data from previous testing or added complex test points to sign off some of these test points, the program must ensure the data are applicable and provide sufficient statistical confidence prior to deleting any underlying build-up test points.
  2. The program should ensure adequate resources remain available (personnel, labs, flight test aircraft) through the completion of IOT&E to develop, test, and verify corrections to deficiencies identified during flight testing.
  3. The program should address the deficiency of excessive F-35C vertical oscillations during catapult launches within SDD to ensure catapult operations can be conducted safely during IOT&E and during operational carrier deployments. (The program made progress working this problem, but testing of potential fixes is not complete.)
  4. The JPO must immediately fund and expedite the contracting actions for the necessary hardware and software

modifications to provide the necessary and adequate Block 3F mission data development capabilities for the USRL, including an adequate number of additional RF signal generator channels and the other required hardware and software tools.
5. The program should address the JOTT-identified shortfalls in the USRL that prevent the lab from reacting to new threats and reprogramming mission data files consistent with the standards routinely achieved on legacy aircraft.
6. The program should ensure Block 3F is delivered with capability to engage moving targets, such as that provided by the GBU-49, or other bombs that do not require lead laser guidance. (GBU-49 is being integrated on the F-35A and C, but is not funded for integration and testing on the F-35B.)
7. The program should complete additional testing and analysis needed to determine the risk of pilots being harmed by the Transparency Removal System during ejections in other than ideal, stable conditions. The program should complete these tests as soon as possible, with the new equipment, including the Gen III Lite helmet in a variety of off-nominal conditions, so that the Services can better assess risk associated with ejections under these "off-nominal" conditions.
8. The Navy and the JPO should investigate alternatives for determining the operational effect of an engine removal and install while conducting carrier air wing operations at sea.
9. The Navy and Marine Corps should conduct an analysis, such as an operational logistics footprint study, which simulates flight deck and hangar bay aircraft placement with a full Air Combat Element (ACE) onboard, using data from the DT-III ship trials to determine what the effect of an engine removal and installation would be on integrated ship and ACE operations with a full ACE onboard. (The Navy has provided historical operational logistics footprint reports to DOT&E and the JOTT has provided data collected during Exercise Dawn Blitz 2017 to DOT&E; analysis is ongoing).
10. The program and the Navy should investigate if the heavy power module container should be redesigned for better usability at sea.
11. The program and the Navy should investigate potential options to improve ship-based communications bandwidth dedicated to ALIS connectivity off-ship, such as increasing the priority of ALIS transmissions, or reserving low-use times of the day for handling large volumes of ALIS message traffic.
12. The Navy should investigate any efficient, multi-use opportunities for F-35 support equipment (SE) such as using legacy SE on the F-35 or F-35 SE on legacy aircraft.
13. The Navy should investigate options for increasing the number of wall power outlets in CVN hangar bays to help facilitate simultaneous maintenance on multiple F-35Cs, or the ability to interconnect multiple pieces of support equipment from a single outlet to permit simultaneous operations.

- FY17 Recommendations.
  1. The program should re-plan C2D2 to have a more realistic schedule and content that include adequate test infrastructure (labs, aircraft, and time) and modifications while aligning the other fielding requirements, like mission data, training simulators, and airworthiness.
  2. For the USRL, the program must:
     - Immediately provide adequate resources within the FY19 DOD program review cycle to fully equip the USRL with software tools and hardware lines, including enough signal generators, to support new C2D2 capabilities and the many fielded configurations with timely and validated mission data.
     - Complete end-to-end cybersecurity testing of the laboratory test lines
     - Provide the USRL with adequate technical data for lab equipment and enough spare parts and supply priority to quickly repair key components.
  3. The program should complete contract actions for another F-35B ground test article as soon as possible to begin additional durability testing.
  4. The program, in coordination with the Services, should stand up intermediate-level maintenance capability as soon as possible, particularly to support deployed aircraft and ship-borne operations.
  5. The program should review reliability and maintenance data from test and operations and provide an updated sustainment cost estimate based on actual data and trends. This updated estimate should include assessments of sustaining aircraft in older configurations vice modifying them to current configurations.
  6. For ALIS, the program should:
     - Develop an adequate ALIS test venue to ensure ALIS capabilities are well-tested prior to fielding to operational units
     - Fully complete end-to-end cybersecurity testing on all three levels of ALIS.
  7. The program should immediately address and seek to remediate all identified cyber vulnerabilities from previous rounds of cybersecurity testing and expand test venues to include software integration labs and maintenance aids (e.g., MATRIX).
  8. The program and Services should conduct testing of "unplugged" aircraft operations without access to ALIS for extended periods of time in light of current cybersecurity threats and vulnerabilities, along with peer and near-peer threats.
  9. The program should complete testing of all required aircraft instrumentation, including integration with the test ranges prior to the formal start of IOT&E. This include the Air-to-Air Range Infrastructure system, Air Warfare Battle Shaping system, and flight certification for the Data Acquisition Recording and Telemetry pod. These instrumentation capabilities are required for test adequacy during IOT&E.